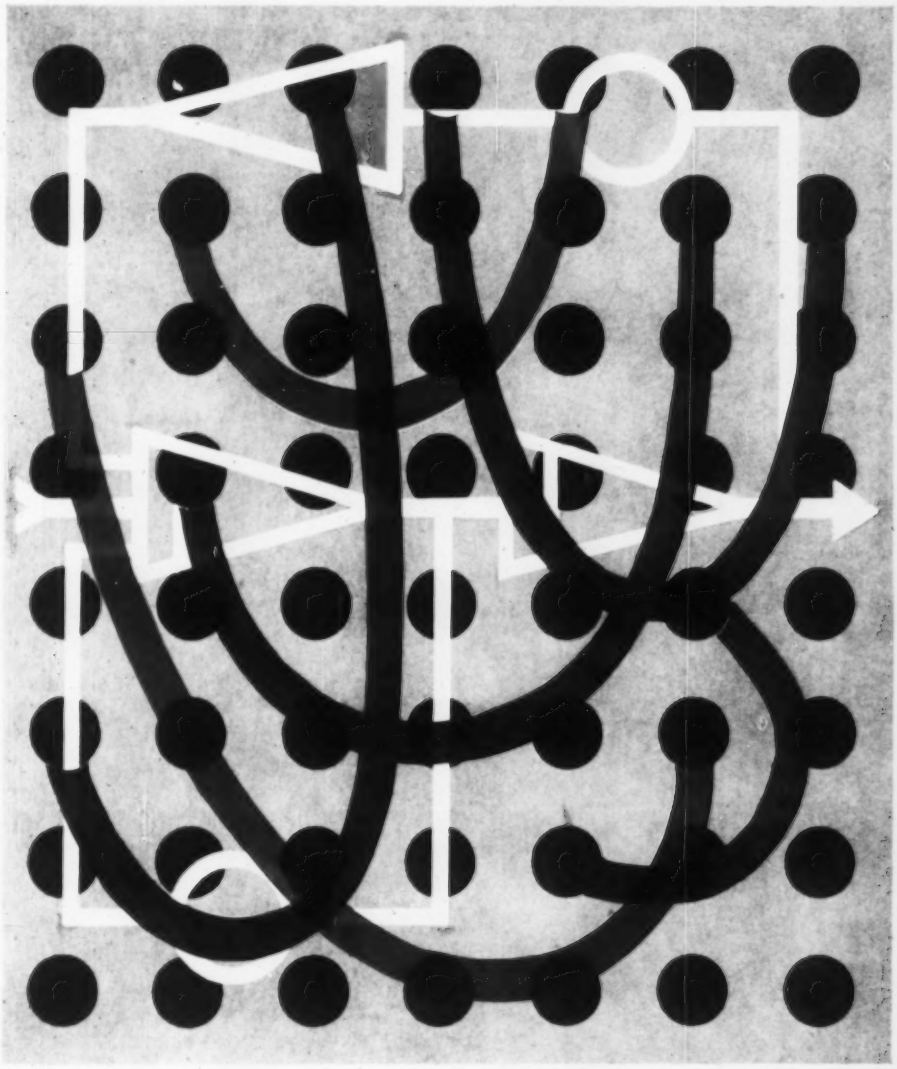
INSTRUMENTS AND CONTROL SYSTEMS

INCLUDING: INSTRUMENT MANUFACTURING • JOURNAL OF THE SCMA • SIMULATION COUNCIL NEWSLETTER



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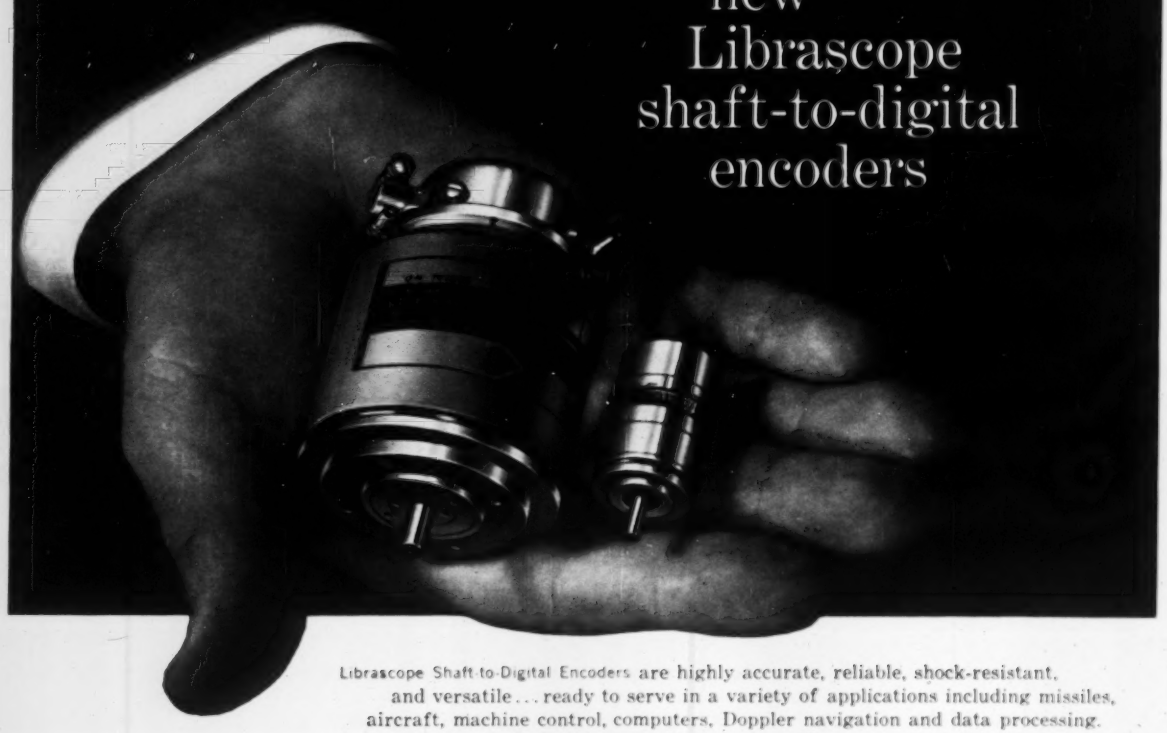
THIS PRINTING: 39,100

NO OTHER LINE SO COMPLETE · 38 NEW ENCODER MODELS · SIZE 8
MAGNETIC
SINE/COSINE · GRAY
SELF-DECODING · NO OTHER LINE SO COMPLETE

new Librascope shaft-to-digital encoders



Librascope Shaft-to-Digital Encoders are highly accurate, reliable, shock-resistant, and versatile... ready to serve in a variety of applications including missiles, aircraft, machine control, computers, Doppler navigation and data processing. Accuracy that counts is the by-word of a Librascope Encoder... backed by the superior technology and reputation of one of the world's largest producers of *Computers that Pace Man's Expanding Mind.*

new noncontact magnetic encoder

MODEL NO. 807

FEATURES:
Long life, high reliability, high speed, natural binary V-Scan readout.

SPECIFICATIONS:
Output Code: natural binary
Resolution: (per input shaft turn) 128 counts
Full Scale Capacity: 7 bits*
Speed: operating from 0 to 10,000 rpm
Life Expectancy: 20,000 hours at 4,000 rpm; 4 x 10^9 revolutions
Starting Torque: 0.1 in-oz. max.
Diameter: 2"
Length: 1 13/16"
Weight: 5 ounces

*ALSO AVAILABLE IN 13, 17, AND 19 BIT CAPACITIES.

new subminiature size 8 encoder

MODEL NOS. 787 & 793

FEATURES:
Low torque, low inertia, long life, high reliability, withstands severe environments.

SPECIFICATIONS:
Output Code: natural binary
Resolution: (per input shaft turn) 128 counts
Full Scale Capacity: 7 bits, 13 bits
Speed: operating 200 rpm, slew 600 rpm
Life Expectancy: 2 x 10^6 revolutions at 200 rpm
Starting Torque: 0.5 oz-in. maximum
Diameter: .750"
Weight: 3 ounces

other popular Librascope encoders

Code	Model no.	Full scale capacity	Resolution per input shaft turn
Binary	773	13 bits	128 counts
	0-773	oil-filled unit for increased life	
Binary	710	10 bits	1024 counts
	707 (707D*)	7 bits	128 "
	713 (713D*)	13 bits	128 "
Binary	717 (717D*)	17 bits	128 "
	719 (719D*)	19 bits	128 "
	0-713	oil-filled unit for increased life	
Self-Decoding Binary	740	10 bits	1024 counts
	723 (723D*)	2,000 counts	200 "
	724 (724D*)	20,000 "	200 "
B/C/D	733 (733D*)	3,600 "	200 "
	734 (734D*)	36,000 "	200 "
	735	360,000 "	200 "
Sine/Cosine	757-S**	4 quadrants per turn	7 bits per quadrant ± limit 1
	758	4 quadrants per turn	8 bits per quadrant ± limit 1
	758-S**		
Gray	708	8 bits	256 counts

*Contain isolation diodes for multiplexing

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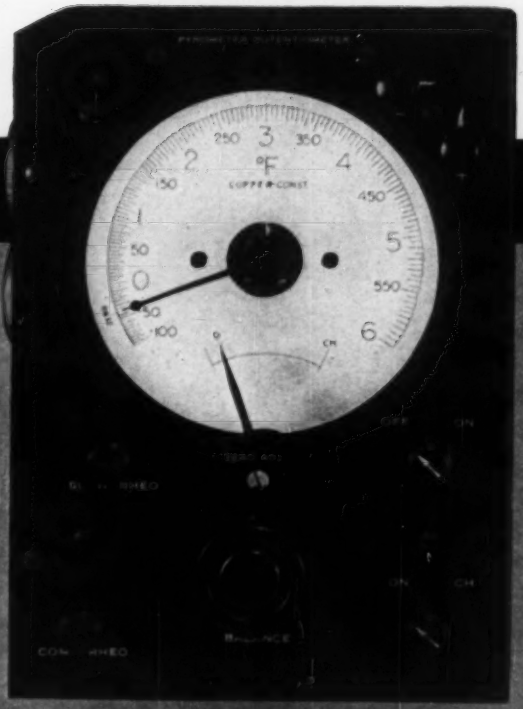
LEWIS

Portable

MODEL 73PO

PYROMETER POTENTIOMETER



FOR MEASURING TEMPERATURES *Electrically*

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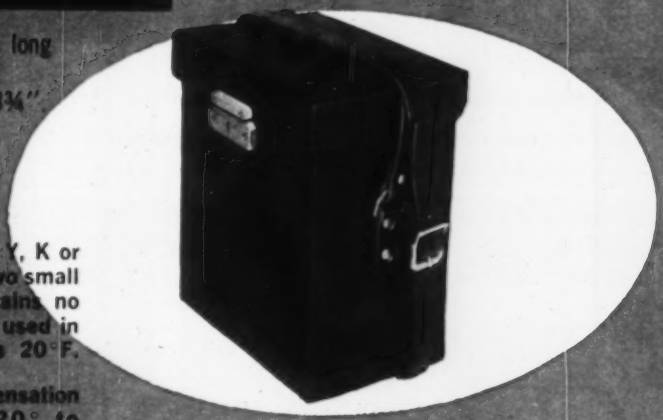
- IN AIRCRAFT
- IN THE LABORATORY

AND FOR MOST INDUSTRIAL APPLICATIONS

Choose from 30 standard scale ranges.

Hand drawn Scales, eight inches long for easy readability.
Aluminum Case 5⅜" x 7¼" x 3¼"
Weight only 4 pounds 10 ounces.



Calibrated for use with Type J, Y, K or T thermocouples. Operated by two small flashlight cells, the 73PO contains no standard cell to freeze, can be used in temperatures as low as minus 20°F.

Electrical cold junction compensation insures accuracy from —20° to +120°F. ambient temperatures.

You CAN take it with you in a convenient leather carrying case, available at extra cost.

THE LEWIS ENGINEERING CO.
Specialists in Electrical Temperature Measurements
NAUGATUCK, CONNECTICUT

CIRCLE 2 ON READER-SERVICE CARD

The "COMMANDER" instruments described below have a 5-year accuracy guarantee. By using NBS or NRC reported values, total cumulative errors for a complete measurement system can be as low as ±.002%.

DAUPHINEE POTENTIOMETER TYPE 9144

ACCURACY ±.001%

A 7-figure (above 1 V.) DC vernier potentiometer with a total measuring range of 2.101010V. *Accuracy is at least 10 x that of similar commercially available equipment.* Direct readout on 4 dials in increments of .1 μv (no slidewire). Thermal emf's less than .1 μv. Switch controlled ranges of x 1 & x .1. Contains 2 saturated standard cells in an internally thermostated enclosure. Completely "Self-Checking." *May be used with equal facility and accuracy as a Saturated Standard Cell or Resistance Comparator — and for the calibration of .01% accurate potentiometers.*

The Type 9144 is an original design by Dr. T. M. Dauphinee of the National Research Council in Canada. All rights are protected by a United States patent application.

VOLT RATIO BOX TYPE 9700

ACCURACY ±.005%

A volt ratio box similar to that used by the National Bureau of Standards as described by NBS Research Paper RP 1419. Self-heating and surface leakage negligible. Ranges: .15/.3/.45/.6/.75/1.5/3/4.5/6/7.5/15/30/45/60/75/150/300/450/600/750 V. (Type 9700A includes 1500 V. range). Furnished in a thermostated oil bath with a motor-driven impeller.

CONSTANT TEMPERATURE STANDARD CELL ENCLOSURE TYPE 9152 AND SATURATED STANDARD CELL TYPE 4305

ACCURACY ±.001%

Enclosure accommodates up to 4 cells and is air thermostated at 28°C ± .025°C. Transistorized circuit. Operates on 110V/60 cps (Battery standby).

THE TYPE 5214 GALVANOMETER AMPLIFIER AND TYPE SR21 LIGHT SPOT GALVANOMETER.

The amplifier operates on the differential photocell principle in conjunction with a liquid-filled primary galvanometer. The secondary galvanometer has a scale length of 120-0-120 mm and is stable and free from the effects of external vibration. Over-all sensitivity is approximately 350,000 mm/μa and 35,000 mm/μv. It is ideally suited for use with the type 9144 potentiometer.

Sensitive Research "COMMANDER" Instruments are manufactured by Guildline Instruments, Ltd. (formerly Tinsley Instruments (Canada) Ltd.)

SENSITIVE RESEARCH INSTRUMENT CORPORATION

NEW ROCHELLE, N. Y. *ELECTRICAL INSTRUMENTS OF PRECISION SINCE 1927*

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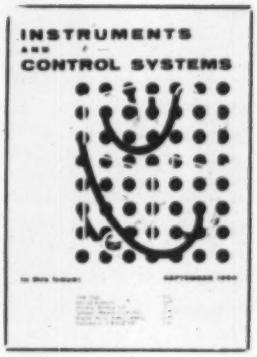
INSTRUMENTS AND CONTROL SYSTEMS



PATCHBOARD for an analog computer keynotes this month's special presentation of basic articles on analog computers. Series begins on page 1540.

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INSTRUMENTS AND CONTROL SYSTEMS

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a new look in counters

AND NEW RELIABILITY, TOO

CMC was first to introduce the all-transistor 10 megacycle counter. Now CMC scores another important first with its complete new line of vacuum tube counting, timing and frequency measuring equipment. Note the clean, functional lines of these tastefully styled instruments... user engineered to eliminate costly "cockpit trouble". These instruments are the most reliable vacuum tube counters ever built. In the counter-timer below, for example, nine tubes have been eliminated. New modular circuitry simplifies maintenance and reduces weight. Unitized construction is exceptionally rugged. And to further simplify matters, all models have three key components in common—input amplifiers, power supplies, and shaping circuits. In short, these instruments will give you long, trouble-free operation.

BUT SEEING IS BELIEVING—Your nearby CMC engineering representative will be happy to arrange a demonstration and provide complete technical data. Or you can write us direct, Dept. 559.

CMC's Model 226B Universal Counter-Timer (1 mc) leads a complete new line which includes a 220 kc universal counter-timer, a time interval meter and a frequency-period meter.

PRICES:
Model 226B, $1175; Model 226BN, illustrated, $1445 with Nixies; Model 225C, $900; Model 203B, $995; Model 251B, $915. Rack mount $10 extra. F.O.B. Sylmar, California.

CMC 32

Computer Measurements Co.

A Division of Pacific Industries

12970 Bradley Avenue, Sylmar, California

Phone: EMpire 7-2161

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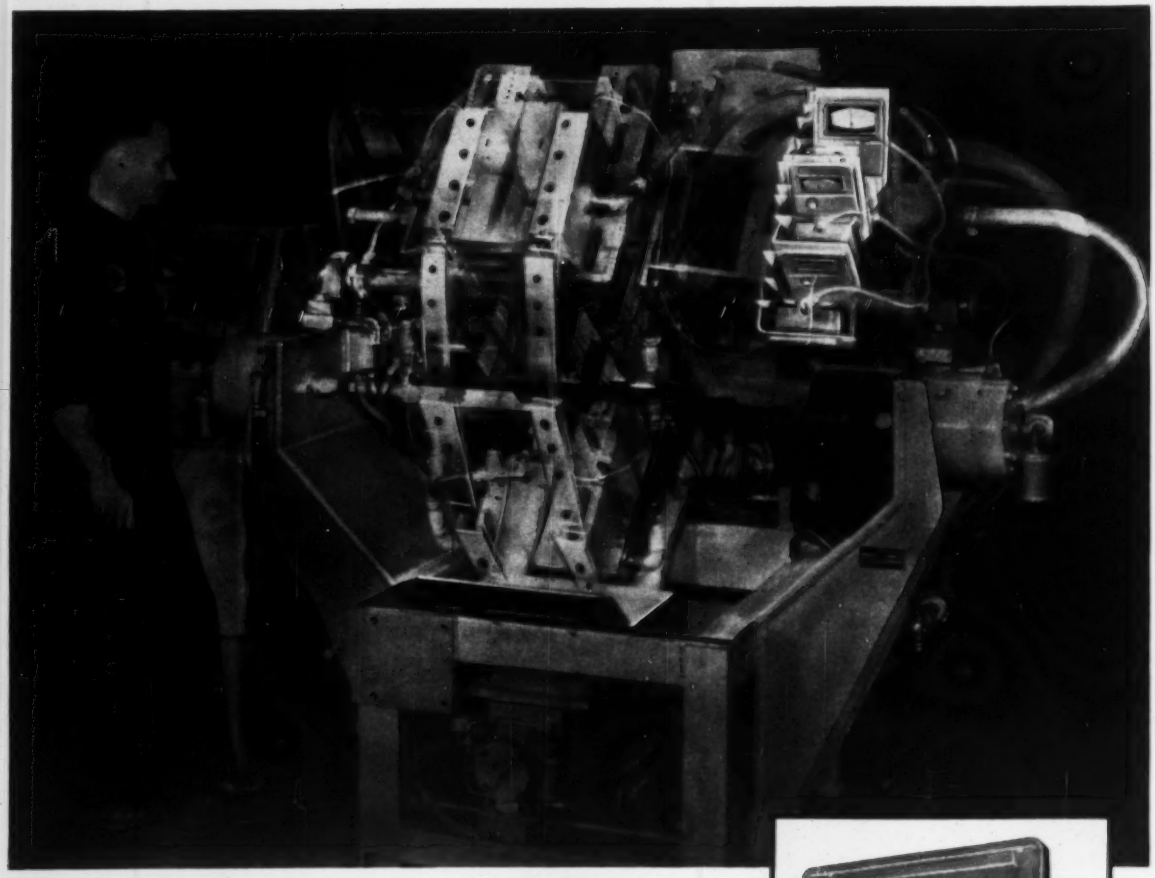

A Partlow Model MFS indicating controller is shown in action in this "multiple exposure" shot of a Holo-Core Automatic Molding Machine manufactured by Spo, Inc., Cleveland, Ohio.

The Temperature Control Built to
SHRUG OFF SHOCK
2438 Times a Day

Every working day, the Partlow Temperature Control in this photo takes between 2400 and 2500 solid "roundhouse punches" from the shell-molding machine to which it is attached.

But despite jarring shock and vibration, and a constant barrage of foundry dust, the Partlow goes right on delivering precision control—without letup or breakdown.

Actually, only a control as simple and rock-solid as the Partlow could withstand this kind of punishment! Because only the Partlow contains no hairsprings, or delicate gadgets.

All Partlow thermal elements of the same range are interchangeable *on the job*, too. There's no time lost waiting for your control to come back from the factory. And you get this extra margin of dependability *without loss of accuracy*. Partlow controls are precise to within 1% of scale in any one of 10 ranges from -30° to 1100° F.

If you use or manufacture equipment within this temperature range, there's a Partlow to fit your application exactly . . . and save you money, too. Available in Pneumatic, Electric or Self-Contained Gas types, in recording, indicating or non-indicating models! To field test any Partlow control . . . or to obtain full details write, The Partlow Corporation, New Hartford, N. Y. Dept. IA-960.

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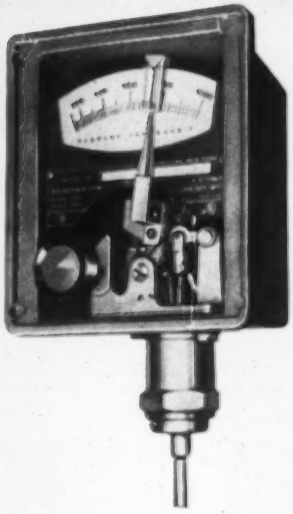


A complete absence of gadgets and superfluous parts, as seen in this open view of the new MFS indicating control, explains the Partlow's unique ability to function accurately even under the most severe operating conditions.

You can pay more but you can't buy better than

PARTLOW

TEMPERATURE CONTROLS

CIRCLE 5 ON READER-SERVICE CARD

LETTERS TO THE EDITOR

Editor, I&CS:

I read the article ["Are We Short in Instrumentation," by E. Cartotto] in the July 1960 issue of *INSTRUMENTS AND CONTROL SYSTEMS* with great interest. I was somewhat surprised by (the author's) statement, "Measurement of low temperature is difficult because transducers frequently display poor mechanical integrity under test conditions; wire thermometers fail because of material limitations and generally lack response."

Our firm has been concentrating heavily in this field, specializing in platinum resistance thermometry. Our calibration procedures have become well developed for the temperature range down to about —435°F. Independent calibrations in our Quality Control Department and in several customer's laboratories by independent methods demonstrate that 0.1°F absolute accuracy can be guaranteed safely, and probably considerably better. At the same time, we have upgraded these devices so that they can withstand extremely severe flow conditions, even with vibration present, the principal limiting factor being the transverse loading which causes the stainless-steel stem to bend.

The author may have in mind another order of magnitude of accuracy, or somewhat different problems.

Frank D. Werner, Pres.
Rosemount Engineering Company
Minneapolis 24, Minn.

The author replies:

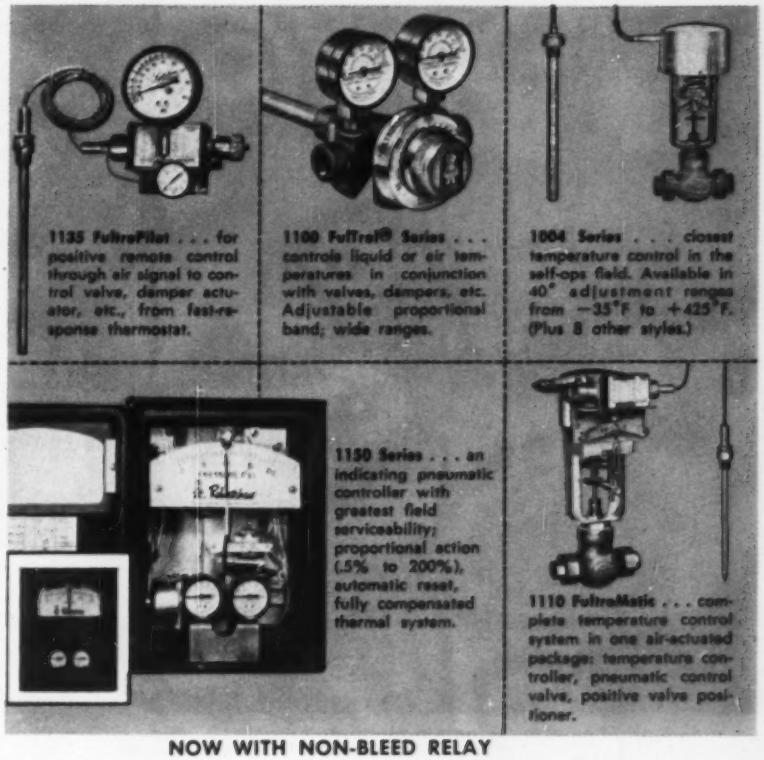
Dear Dr. Werner:

Rocketdyne uses large quantities of your (Rosemount) resistance thermometers as well as those supplied by other manufacturers. I can appreciate your concern for my comments regarding transducer failure because you certainly have shown interest in keeping up with customer requirements. Perhaps my statement should have been "transducers occasionally display poor mechanical integrity under test conditions." And it is this "occasional" failure that is so troublesome. In tests of 300 milliseconds' duration, much depends on the survival of transducers. During these tests the environment severely taxes instruments.

Vibration and fluid forces have accounted for almost all failures of thermometers. When one realizes

Continued on page 1449

Sure Control at Low Cost ...and Quality All the Way!



1135 FultroPilot . . . for positive remote control through air signal to control valve, damper actuator, etc., from fast-response thermostat.

1100 FulTrol® Series . . . controls liquid or air temperatures in conjunction with valves, dampers, etc. Adjustable proportional band; wide ranges.

1004 Series . . . closest temperature control in the self-ops field. Available in 40° adjustment ranges from —35°F to +425°F. (Plus 8 other styles.)

1130 Series . . . an indicating pneumatic controller with greatest field serviceability; proportional action (5% to 200%), automatic reset, fully compensated thermal system.

1110 FultroMatic . . . complete temperature control system in one air-actuated package: temperature controller, pneumatic control valve, positive valve positioner.

NOW WITH NON-BLEED RELAY

From the rugged simplicity of self-ops to the more complicated requirements of an indicating controller, Robertshaw answers your temperature control need[illegible]

PLUS GREAT NEW PRODUCTS AT THE ISA SHOW
Booth 1211—New York Coliseum

[illegible] performance.

Check the Robertshaw temperature and pressure controls for *your* needs. You'll find them shown in detail in Catalog A-RL

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MR. CONTROLS
Robertshaw-Fulton Controls Co.
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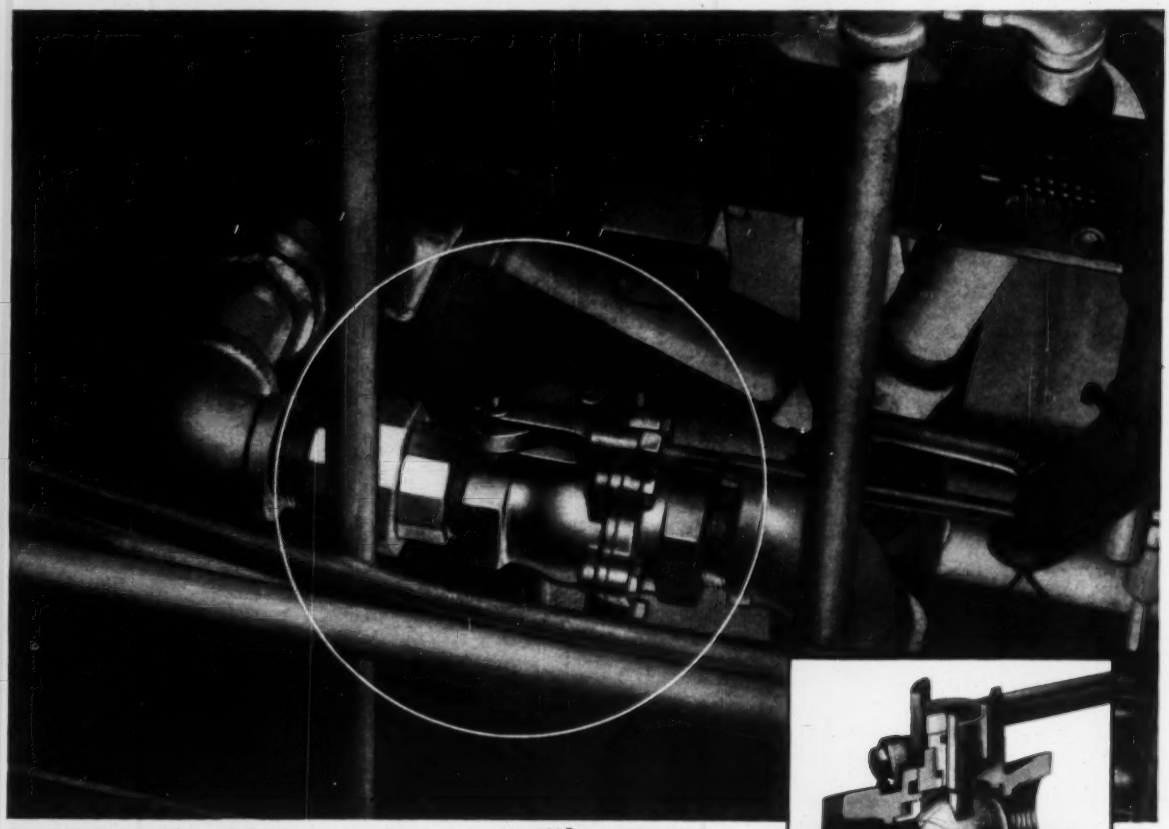
CLEANLINESS COUNTS *in big, fast can washer*



One of the Rockwood Bronze Ball Valves used on cleansing line — size 1¼" — in a *Straightaway* Can Washer built by the R. G. Wright Co., Inc., Buffalo, N. Y., for milk companies and other users.

ROCKWOOD Ball Valves simplify operation and maintenance

In *Straightaway* Can Washers Rockwood Ball Valves are used for washing with a detergent solution and rinsing with sterile water, at temperatures of 135°F. to 180°F. Aid in processing up to 15 large cans per minute, in preventing seepage of wash solution into mechanism and in reducing maintenance to minimum are provided by these Rockwood Ball Valve advantages:

Full Round Flow. No change in shape or volume of fluid stream — no turbulence — minimum loss.

Leakproof Seal. Exclusive spring rings compensate for pressure variations, temperature effects, etc.

Quick Opening and Closing. Only a quarter turn needed.

Long Wear-Resistance. Chrome-plated bronze ball withstands abrasion, pitting and scratching.

Rockwood Ball Valve sizes run from ⅜" to 2" in bronze and up to 10" in cast steel. Equipment manufacturers and processing plants depend on them for proved full round flow and protection of product and performance in the widest range of processing. Tested and listed by Underwriters' Laboratories, Inc. Write today for full information. ROCKWOOD SPRINKLER DIVISION, 1029 Harlow Street, Worcester 5, Massachusetts. Distributors in all principal industrial areas.

ROCKWOOD BALL VALVES

CIRCLE 7 ON READER-SERVICE CARD

LETTERS TO THE EDITOR

Continued from page 1447

that these forces sometimes shear the retaining bolts of flowmeters, causing the turbine wheel to crash downstream, it is not hard to understand that other transducers also will fail under action of the same forces.

Unquestionably, the accuracy of platinum resistance thermometers is excellent. Having gone uncha'lenged for many years, I can understand your questioning if another order of magnitude of accuracy is being expected of platinum thermometers. Actually, the answer is "yes." Although the frequency with which such requests are made is small, we expect that it will increase in the near future.

You will recall the statement, "The manufacturer has done well, . . .". This was said in seriousness. If my article has caused manufacturers to just take another look at their products and ask "Are we really trying to help solve their problems?", I believe the article has served its purpose.

Ed Cartotto
Rocketdyne Division of
North American Aviation
Canoga Park, Calif.

Editor, I&CS:

We are establishing a small electrical and physical standards laboratory here at General Atomic. I would very much appreciate a reprint of an article appearing in the November 1957 issue of your fine magazine entitled "Equipment for a Standards Lab." by W. M. Kidwell. You have published many other fine papers on this same subject such as "Setting Up a Standards Laboratory," January 1959, by Philip Greenspan. All of these would be extremely helpful to us.

Quite frankly, I believe that you have done such a fine job along these lines that a bound volume which would include your better papers on standards would be useful to every engineer doing research work.

J. H. Cawley
Research Staff Member
General Dynamics Corp.
San Diego, Calif.

A "bound volume" of these articles is available—the 84-page *HANDBOOK OF ELECTRICAL MEASUREMENTS—with 26 articles from I&CS.* It is available only with a new or renewal subscription to *I&CS.*

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Like all other CEC galvanometers, it's a self-contained, sealed unit that's been made to extremely close tolerances and rigidly tested in more than 30 quality control checks.

But its performance is what makes this instrument unusual. CEC galvanometers offer the ultimate in high-performance characteristics. They're available in 14 types with a wide range of frequency response.

What has all this to do with the fragile, bulky galvanometers of 22 years ago? Plenty. In 1939, CEC research and development created a totally new design concept that has meant technical superiority ever since. For complete information on the best galvanometers made for *your* oscillograph, write today for Bulletin CEC 1528-X5.

See the new CEC Oscillographs at Booth 1712, ISA, Sept. 26-30

Transducer Division CEC

CONSOLIDATED ELECTRODYNAMICS / pasadena, california

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Nash Instrument Air Compressors deliver only clean air, free from oil or dust, and without filters
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DISCHARGE PORT
DISCHARGE PORT
INLET PORT
ROTATION IS CLOCKWISE

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You can dispense with oil filters and dust filters when you install ®Nash® Clean Air Compressors. You can save the cost of maintaining these devices. You can greatly reduce instrument maintenance costs. For the Nash employs no internal lubrication, therefore no troublesome oil is in the delivered air. Moreover, air from a Nash is thoroughly washed and cooled as it passes thru the pump. Dust in the plant atmosphere, even fly ash, is immediately removed.

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No oil filters.
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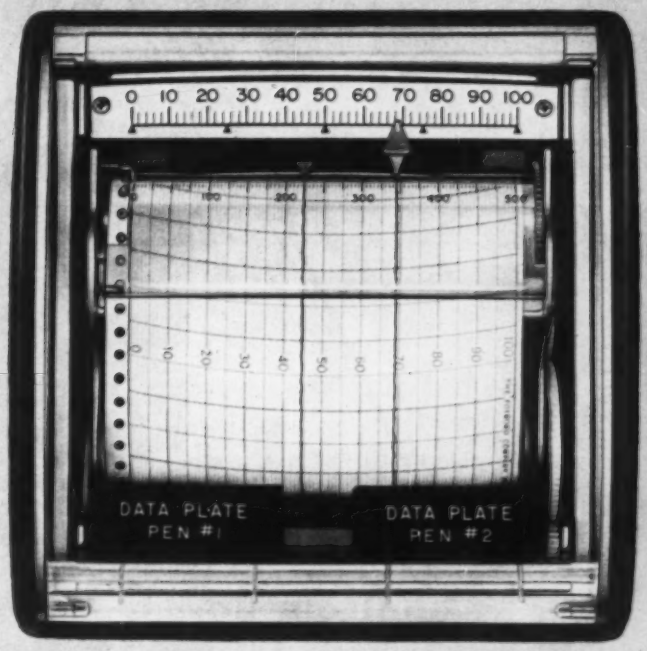
Non-pulsating pressure.
Original performance constant over a long pump life.
Low maintenance cost.

NASH ENGINEERING COMPANY

370 WILSON, SO. NORWALK, CONN.

another unit in Foxboro's **exclusive** 100% solid-state electronic Consotrol* system

Simplest most reliable electronic recorder yet!



Foxboro M/64 Electronic Consotrol Recorder

no amplifiers...no electrical adjustments

The precision and speed of electronics...*plus* the simplicity and reliability previously associated only with pneumatics. That's the new Foxboro M/64 electronic Consotrol recorder.

The M/64 uses a powerful magnetic torque motor to operate pens directly from a high-level 10-50 ma d-c signal. There's no amplification necessary—no slidewire or rebalancing unit. 4-inch vertical strip chart gives full-scale readability of records. One and two-pen models available for semi-hazardous or non-hazardous service.

The M/64 slides out of its housing like a drawer, so all servicing may be done from the front of the panel. Yet there is no interruption to recorder operation! What's more, zero, span, and linearity are all simple mechanical adjustments, so familiar to pneumatic instrument users.

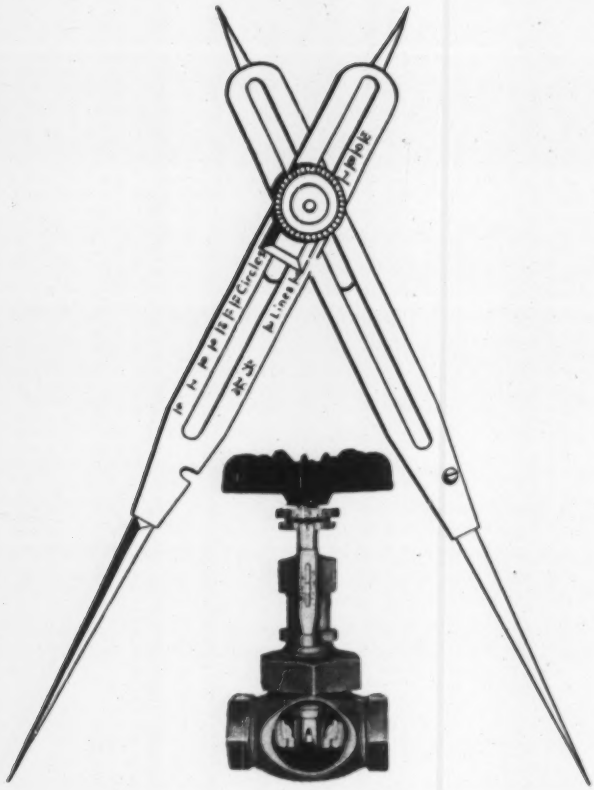
Write today for Bulletin 21-10. It describes the new M/64 Recorder in detail, as well as the many other advanced instruments in Foxboro's complete 100% solid-state electronic control system. **The Foxboro Company, 4612 Neponset Ave., Foxboro Mass.**

*Reg. U.S. Pat. Off.

FOXBORO
REG. U.S. PAT. OFF.

ELECTRONIC CONSOTROL INSTRUMENTATION / for every function in the control loop

CIRCLE 9 ON READER-SERVICE CARD



PROPORTIONER

controls flow to save for you

The V-port disc in all Hancock "Flocontrol" Valves insures proportional flow throughout the entire lift of the stem. They are valves that help you achieve uniform product quality through closer control, save steam and fuel on process work, and cut maintenance costs.

"3 in 1" valve design combines variable orifice with shut-off and micrometer dial and pointer. The valve opening can be set within 1/10 turn of the handwheel —you can duplicate all settings easily, instantly. No shut-off valve required—flow is in a straight line, with separate shut-off seating surface located away from the V-ports.

Hancock "Flocontrol" Valves are available in Bronze and Steel to meet the most demanding services. Ask your industrial supply distributor for details.

Hancock "Flocontrol" valves assure positive pinpoint control—eliminate all guesswork.

MAXWELL MANNING & MOORE INC. M&M TRADE MARK

HI-99

HANCOCK "FLOCONTROL" VALVES

A product of

MANNING, MAXWELL & MOORE, INC.

Valve Division • Watertown, Massachusetts

In Canada: Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario

CIRCLE 10 ON READER-SERVICE CARD

LETTERS TO THE EDITOR

Editor, IC&S:

Would it be possible to obtain authorization to make use of substantial portion of articles that appeared in the June, 1960 issue of *INSTRUMENTS AND CONTROL SYSTEMS*? These articles are (1) The Gyroscope, page 958, and (2) Electronic Control of Pipelines, page 972.

We would like to use the information in texts we are currently preparing on Electronic Instrumentation and Control.

This is a good opportunity, too, to say something that I have wanted to for quite some time now—"Congratulations on publishing such a fine magazine as *INSTRUMENTS AND CONTROL SYSTEMS.*"

Joseph A. Risse, Director
International Correspondence Schools
Scranton 15, Pa.

We are happy to help any and all education efforts, of which the ICS courses are among our nation's best.

Editor, I&CS:

I have just returned from seven weeks in Europe where I visited many standard labs—NPL in England, The International Bureau in France, PTB-Berlin and PTB-Braunschweigh in Germany.

The *Handbook of Electrical Measurements* is excellent. Are extra copies available?

James B. Kelley
Physics Research Laboratories, Inc.
Hempstead, N. Y.

The Handbook is available (no extra charge) only with a subscription (or renewal) to *INSTRUMENTS AND CONTROL SYSTEMS.*

Editor, I&CS:

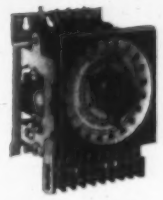
Thanks for the mention of our new voltage divider (page 1198, July, *I&CS*). However, it was reported as a "shielded resistor" and no mention was made of its basic use—a high voltage divider for use in the range from 1.5-50 kv.

Chas. White
AVCO, Research & Advanced Dev.
Wilmington, Mass.

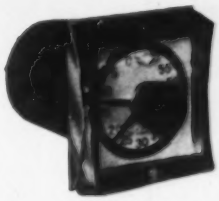
EAGLE

QUALITY BUILT • EASY TO USE

timers and counters



Bulletin 110
20 TURN DIAL RESET TIMER

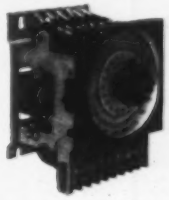


Bulletin 125
SINGLE CYCLE RESET TIMER

Bulletin 165
PNEUMATIC TIME DELAY RELAY

Bulletin 170
TIME DELAY RELAY

Bulletin 320
ADJUSTABLE REPEAT CYCLE TIMER



Bulletin 720
AUTOMATIC RESET COUNTER

Now in stock for immediate delivery

To better serve your needs without delay, EAGLE now makes available the above Timers and Counters for immediate delivery direct from factory stock or stocking sales representatives in principal cities.

When you use EAGLE Timers and Counters, you are assured of selecting the finest quality and most dependable components you can buy.

Write us regarding your TIME-COUNT problems, or see your local phone directory or Thomas Register under the heading, "TIMERS, ELECTRIC" for your nearest EAGLE Representative.

VISIT US AT THE PRODUCTION ENGINEERING SHOW SEPT. 6-16
NAVY PIER, CHICAGO—BOOTH NO. 381

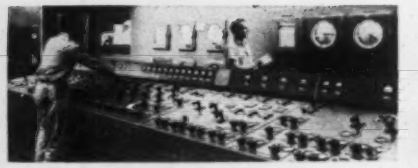
BLISS

EAGLE SIGNAL COMPANY • Moline, Illinois

A DIVISION OF THE GAMEWELL COMPANY, AN E. W. BLISS COMPANY SUBSIDIARY

MANUFACTURERS OF THE MOST COMPLETE LINE OF INDUSTRIAL TIME-COUNT CONTROLS

CIRCLE 11 ON READER-SERVICE CARD



HAGAN NEWSLETTER—SEPTEMBER

Behind the panel

HOW "CENTRALIZED CONTROL" ADDS DRAMATIC EXTRAS TO OPEN HEARTH DUST COLLECTION

A major Pittsburgh steel producer, cooperating with the city's air pollution control program, is installing electrostatic precipitators on eleven open hearth furnaces. Hagan PowrMag electronic controls, Ring Balance meters, and a Kybernetes TIM (temperature indicating monitor) are playing an important role in the over-all automation of the eight precipitators, and the eleven waste heat boilers that cool furnace gases ahead of the precipitators.

The steel company will obtain these positive benefits from the system; benefits that were taken into account when justifying the initial investment:

1. Effective control of troublesome open hearth dust.
2. Recovery of iron ore from the dust.
3. Bonus steam from the waste heat boilers.
4. Most important of all, intelligent automation of the process to minimize operating costs.

THE CONCEPT OF CENTRALIZED CONTROL IN ACTION

Early planning for the job envisioned a control panel at each boiler and precipitator. However, when operating and supervisory requirements were spelled out, the thinking quickly evolved towards complete centralization of control. Hagan PowrMag (solid-state, magnetic) controls reach out from a single 80-foot control house to control equipment spread out over an open hearth shop more than ¼-mile long.

The Hagan Kybernetes TIM (the steel industry's first, for this process) will provide high-speed warning if any of 220 critical gas, bearing, or steam temperatures get out-of-limits; it will also monitor various pressures and levels. Thus, the operator has continuous, automatic supervision of the plant from the central control house.

A graphic control panel will present clear operating information at all times, and further centralize the operation of the coordinated systems. (Details on request--ask for Item 0-1.)

80,000 POUND--500 MPH TIRE TESTER HAS HAGAN CONTROLS

The control system is programmed to simulate all of the strains aircraft tires could possibly encounter, including the tremendous impact and yawing which occurs at touchdown on a landing field. Other programming puts the tires through taxiing and take-off tests. A tire may be accelerated from zero to 320 mph in less than 20 seconds under 30,000 pound load. Control systems for the four similar units include: PowrAmp amplifier, a model CPM controller and Hagan electro-hydraulic pilot valves. These Hagan controls have performed beyond expectations on this unusual equipment. (Details on request--ask for Item 0-2.)

"DOUBLE PLAY" SOLVES MOLYBDENUM PRODUCTION PROBLEM

A variation of the classic double play solved a tricky problem for a major molybdenum producer. In this case, it was Hall to Hagan to PowrMag, and here is how it came about. The ore is reduced by the flotation process. The plant found that production was falling off by as much as 5% daily (20,000 lb/day). They asked a Hall Laboratories industrial water consulting engineer for help. Working with plant personnel, the Hall man determined that raising the pH of the mix would stabilize production at the desired high level. This was accomplished by hand-feeding lime slurry, but manual control proved both time consuming and inaccurate. At this point the Hall engineer called on his Hagan counterpart for an assist, since the obvious solution was to make pH control automatic. And here the third member, the Hagan PowrMag (magnetic amplifier) controller, entered the play. Key element in a control system which provides for every quirk in the process, including the substantial cyclic process time lag, the PowrMag controller impressed both management and operating personnel with its simplicity and reliability. Since the entire system, including valve operators, is electronic, installation and maintenance will be simplified. The automatic pH control system is the first step in the automation of a process which tradition has regarded as requiring expert manual control. (Details on request--ask for Item 0-3.)

HAGAN CHEMICALS & CONTROLS, INC., Hagan Center, Room 714, Pittsburgh 30, Pa.

HAGAN DIVISIONS: CALGON CO. — HALL LABORATORIES — BRUNER CORP.

FOR ITEM 0-1, CIRCLE 12 FOR ITEM 0-2, CIRCLE 13 FOR ITEM 0-3, CIRCLE 14

Only VALCOR makes solenoid valves of TEFLON*

*DuPont Company registered trademark.

Now, from the company that pioneered the use of Nylon and PVC in solenoid valves for corrosive service, comes a solenoid valve with a **molded body and diaphragm of Teflon** that is **chemically inert and corrosion-resistant to virtually any corrosive medium you are now using.**

Valcor solenoid valves made of all Teflon are ideal for **critically** corrosive applications and where long life is essential. They will outlast and outperform steel. Available in a variety of sizes and pressure ratings. Stocked for immediate delivery. Write today for complete technical data.

VALCOR SOLENOID VALVES

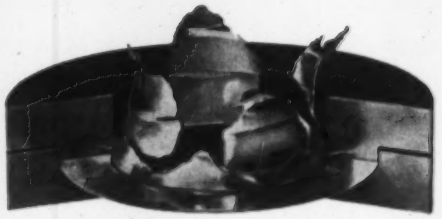
VALCOR ENGINEERING CORP.

5366 Carnegie Ave., Kenilworth, N. J. • CHestnut 5-1665

CIRCLE 15 ON READER-SERVICE CARD

instant and automatic relief of excess pressure with dependable corrosion-resistant rupture discs

BAKER PLATINUM DIVISION



In pressurized apparatus subject to corrosive action, precious metal rupture discs provide the safest, most accurate and dependable relief. Platinum, gold, and silver are now generally recognized as specifics when dealing with corrosion. Each is resistant to the corrosive effects of an important group of liquids and gases and will remain unattacked under conditions that would render many base metal materials useless. These rupture discs, depending on material selected, are guaranteed to be burst ±5% of specified pressure. Intrinsic value adds to the original cost of these discs but the actual metal value is recovered, no matter how torn or battered the discs may be. Send for literature.

BAKER PLATINUM DIVISION • 113 ASTOR STREET
NEWARK, N. J.

These platinum precision resistance spirals measure temperature by change in electrical resistance.

INSTRUMENTS AND SYSTEMS DIVISION

Here are ideal components for both accuracy and reliability in temperature measuring or controlling equipment. They have an accuracy of ± 0.1°C.

Three types are available in a full range of sizes. A glass enclosed series affords high precision for temperatures between −220°C and +500°C. Spirals are obtainable as standard products having a resistance of 25, 50 or 100 ohms. The variation in diameters, lengths, etc., are numerous.

High temperature spirals in which suitable ceramic replaces the glass are also available. These are used for measuring temperatures up to 750°C. The accuracy of the ceramic spirals is only slightly less than that obtainable from the glass spiral, but still superior to thermocouples in stability. For extremely precise temperature measurements, a laboratory standard resistance thermometer is available.

Although most spirals are supplied directly to the user as components, we also provide a fabrication service and supply spirals in metal sleeves or other constructions as required. Send for complete literature.

INSTRUMENTS AND SYSTEMS DIVISION • 850 PASSAIC AVENUE
EAST NEWARK, NEW JERSEY

DOMESTIC DIVISIONS: AMERICAN PLATINUM & SILVER DIVISION • AMERSIL QUARTZ DIVISION • BAKER CONTACT DIVISION • BAKER DENTAL DIVISION • BAKER PLATINUM DIVISION • BAKER SETTING DIVISION • CHEMICAL DIVISION • HANOVIA LIQUID GOLD DIVISION • INSTRUMENTS & SYSTEMS DIVISION • IRVINGTON-BAKER REFINING DIVISION • D. E. MAKEPEACE DIVISION • RESEARCH & DEVELOPMENT DIVISION • H. A. WILSON DIVISION. COMPANIES ABROAD: ENGELHARD INDUSTRIES OF CANADA, LTD., TORONTO • ENGELHARD INDUSTRIES LTD., BAKER PLATINUM DIVISION, HANOVIA PRODUCTS DIVISION, LONDON • SOCIEDAD SURAMERICANA DE METALES PRECIOSOS S.A., BO-

PROMPT PRECIOUS METAL SCRAP RECOVERY SERVICE • ENGELHARD PROCEDURES RECOVER

FOR DISCS, CIRCLE 16 ON READER-SERVICE CARD

FOR SPIRALS, CIRCLE 17 ON READER-SERVICE CARD

AMERICAN PLATINUM & SILVER DIVISION

a simplified mirror-bright silver plating process for electrical and electronic components

Here is the most efficient, simple procedure to protect electrical electronic and lamp components with a mirror-bright silver finish—through a complete range from flash to heavy deposit. The procedure is easy, economical and non-critical —with little or no polishing required. Silva-Brite is a clear, water-white solution, enabling the operator to observe work as it is being plated. Uniformly good results are attained with current densities ranging from 10 to 40 amperes per square foot. Normal room temperature operation minimizes fumes and tendency toward bath decomposition. Send for descriptive data together with detailed plating procedures.

AMERICAN PLATINUM & SILVER DIVISION
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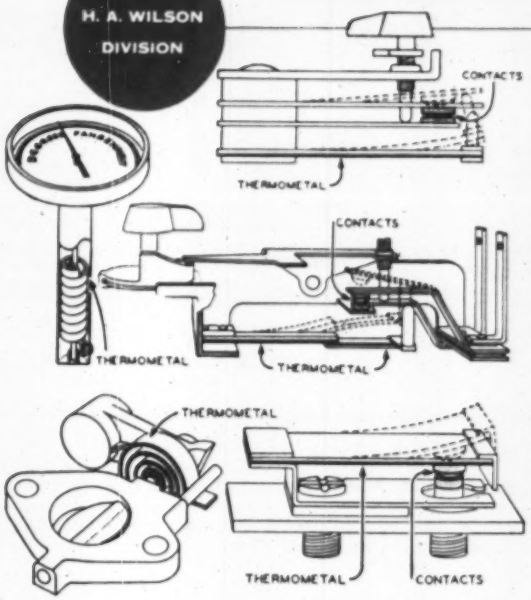
H. A. WILSON DIVISION



THERMOMETAL® for dependable temperature, electrical current and voltage control applications.

Leading manufacturers depend upon the outstanding performance of Thermometal in electrical appliances, thermal cutouts, heating controls and many other applications involving the indication and accurate control of temperatures, electrical currents, voltages, etc. Thermometal is supplied in strip form, rolled and slit to close tolerances and tempered to specification. Thermometal elements and sub-assemblies are also supplied to specifications, with or without contacts attached. Send for literature.

H. A. WILSON DIVISION • U.S. HIGHWAY 22
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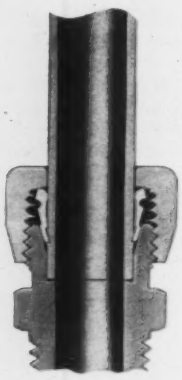
100% OF ASSAYED PRECIOUS METAL CONTENT
FOR PLATING, CIRCLE 18 ON READER-SERVICE CARD

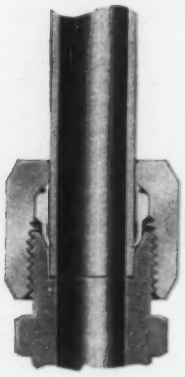
• IRVINGTON-BAKER REFINING DIVISION
FOR THERMOMETAL, CIRCLE 19 ON READER-SERVICE CARD

THESE PARKER TUBE FITTINGS MEET YOUR EXACT NEEDS



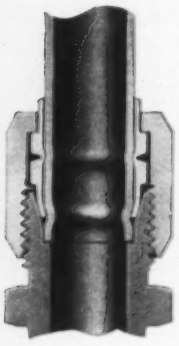
FOR INSTRUMENT AIR

"INTRU-LOK®", the non-flare "bite" fitting for copper, aluminum, Nylon or "Parker-POL" (polyethylene) tubing, features "in true" tube entry for easy make-up. You never need to disassemble this fitting . . . just insert the tube end and tighten the nut. Ask for catalog No. 4324.



FOR HIGH PRESSURES

"FERULOK®", the heavy-duty flareless fitting with the visible bite . . . you can see it, inspect it, make sure you have safe make-up. Usable with heavy-wall tubing for high pressure applications. Excellent vibration resistance. Made in steel, stainless steel, Monel. Ask for catalog No. 4320.



COMPLETELY CORROSION RESISTANT

"RIDG-LOK", the all-stainless-steel (type 316) fitting for critical corrosion resistance applications. Unique ferrule design provides a safe, dependable, non-flare grip. Ferrule is "foolproof", with identical ends so there is no possibility of putting it in backwards. Ask for catalog No. 4322A.

Instrumentation and processing call for specific fittings—not a "general" type

It pays to be selective . . . to get the precise fitting for the job. Parker "Intru-lok®" is right for instrument air . . . small envelope, simple assembly, reasonable price. "Ferulok®" takes high pressures, assures safety from blowout. "Ridg-lok" is completely corrosion resistant.

No single fitting is right for every job. Parker fittings give you what you pay for – and what you need. *And there's a Parker fitting for every specific application.* For flared tubing, the Parker 37° "Triple-lok®" fitting is the leader.

For complete specifications and engineering help, check your nearest Parker distributor through the Yellow Pages, or write direct to:

PARKER HANNIFIN CORPORATION

Parker FITTINGS AND HOSE DIVISION
17325 Euclid Avenue • Cleveland 12, Ohio

PNEUMATIC AND HYDRAULIC SYSTEM COMPONENTS

3171-PH

CIRCLE 20 ON READER-SERVICE CARD

Printed-circuit board market in 1960 is between $28 and $33 million says R. Zens, Electrolab Printed Circuits. This is 10% over 1959. A 10% per year increase is expected annually. Industry uses 40%; military 35%; consumers 25%.

Printed-Circuit board market in 1958 totalled $15.7 million; says Bureau of Census.

National Science Foundation estimates that total basic research in the United States reached a level of $1 billion in year 1959-60, compared to $430 million in 1953-54, $830 million in 1957-58. Throughout this period, funds for basic research continued at a level of about 8% of the total estimated R&D funds, which reached a $12 billion annual level for 1959-60 according to the Foundation. Federal government supplied $423 million of $835 million total for 1957-58; industry supplied $249 million; colleges and other non-profit institutions supplied $163 million.

Electronic companies in the 11 western states are growing at a faster pace than the national average and this year will account for 22% of total U. S. electronic sales of $10.2 billion, says Western Electronic Manufacturers Association (WEMA). Figures exclude broadcast, service and distribution revenue. Sales of western companies last year were $1.9 billion, which was 20% of the nation's total of $9.4 billion. By end of 1960 the number of electronic firms in the west will be 840, representing 20% of the projected U. S. total of 4,200.

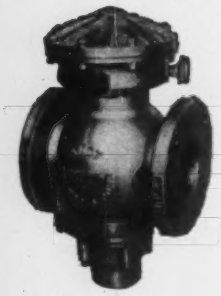
In 1861 the first telegraph line crossed the USA; in 1961 the first transcontinental microwave beam will be operational. It will have 160 relay stations. Bandwidth of telegraph line was a few hundred cycles; bandwidth of each of 6 microwave channels will be 6 Mc (equivalent to 72,000 teletype channels). Equivalent of 2.5 million words can be flashed coast-to-coast every minute.

US had 66,520 aviation aircraft in 1958 says Federal Aviation Agency (FAA). 60.8% had two-way radio. Other electronic equipment: LF/MF receiver—24.4%; VOR receiver—42.5%; ILS—9.7%; ADF or DF—20.7%. Of the 66,520 total, 60,650 were single-engine, 5,370 were multi-engine, 290 were helicopters.

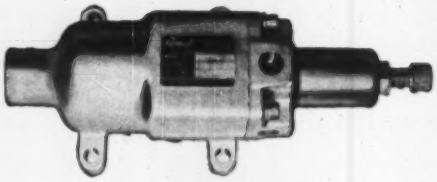
Technicians in firms manufacturing electronic equipment earned from $1.75 to more than $3 per hour in 1958, says US Bureau of Labor Statistics.

Population of USA in 1960 is 179.5 million, compared with 151.3 million in 1950 says Census Bureau. Monthly per capita income has risen from $118 in 1950 to $189 in 1960.

There were 159 midair collisions in the 10 years between 1948 and 1957. Only 4 occurred above 4000 ft. Average collision rate was 1 collision per million flying hours.

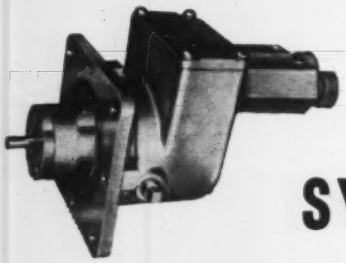


Diaphragm Gas Valves
2" & 3" Pipe Size
Model 2180



Vibration Valve
3-Way Control
Model 2900

Thermostatic Valves
½" to 6" Pipe Size
MODEL B



Speed Actuated Valve
3-Way Control
Model 4017

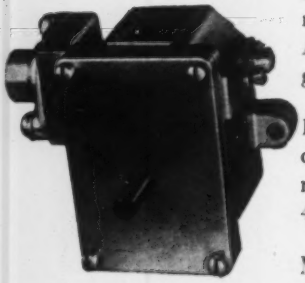
AMOT

SYSTEM CONTROLS

A COMPLETE LINE

Already recognized by owners and original equipment manufacturers as the standard of quality and reliability in engine controls and thermostatic valves, AMOT is expanding its product line to provide greater flexibility in function control.

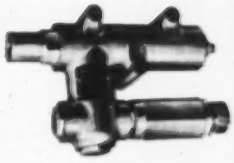
Safety Control Switch
Pressure-Temperature
Model 2340



Low Pressure Safety Control
Small Engines & Equipment
Model 2800

Illustrated on this page are some of the new products designed particularly for automatic or semi-automatic control systems. Models 2900, 4017, 4021, 4023 include 3-way balanced valves.

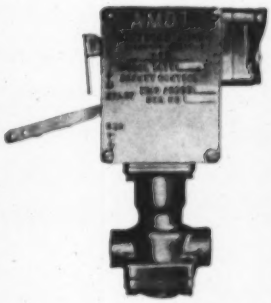
Model 2800 is a new lower priced snap-acting safety shutdown device which is sensitive to low pressure. Now smaller engines can be provided with AMOT quality protection at a price attractive to both builder and user.



High Pressure Valve
3-Way Control
Model 4023

Temperature Valve
3-Way Control
Model 4021

In addition to the products illustrated on this page, AMOT offers temperature actuated valves and switches, diaphragm operated devices, special controls to builders specifications, and the Model 2400 Indicating Relay. This mechanical indicator is widely used in control systems to show the cause of emergency shutdown or trouble, and is available with a snap switch for remote electrical shutdown indication.



Safety and Automatic Controls
Mechanical Type
Model 1476

AMOT CONTROLS CORPORATION

FIRST STREET & NEVIN AVENUE • RICHMOND, CALIFORNIA
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Calgary, Alberta

EUROPE

Amproduct Company
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Vevey, Switzerland

CIRCLE 177 ON READER-SERVICE CARD

IF IT DOESN'T FIT

WHY WEAR IT?

Our former corporate name, Brooks Rotameter Company, used to be adequately descriptive of us. We made rotameters, and that was that. • Now the shoe doesn't fit so well any more. For now we make many diversified flow-measurement instruments. The unique MagPnuTraX™ Flow Transmitter is one example—and other new and advanced designs are on the way. • So we've decided to change our name. From here on out, we'll be known as the Brooks Instrument Company (with an "Inc." added for good measure). • Watch this new name. You'll be seeing it on some of the most talked about instruments in the industry.

BROOKS INSTRUMENT COMPANY, INC.
HATFIELD, PENNSYLVANIA

CIRCLE 21 ON READER-SERVICE CARD

IGS NEWS

Iron and Steel Instrumentation

LONDON, ENGLAND—The annual report of the British Iron & Steel Association (11 Park Lane, London W.1.) for 1959 reports on developments in (1) a photocell method for detecting the end point of a converter process by the brightness characteristic, (2) measurement of temperature of tensile wire during the drawing process, (3) equipment for comparing the shapes of d-c and a-c hysteresis loops, (4) grain boundary studies by optical and electron metallography, chemical extraction, radioisotope diffusion, internal friction, (5) analytical studies by cathode-ray polarograph, potentiometric equipment, spectrophotometry and x-ray fluoroscopy, (6) development of a simple photoelectric-pattern smoke density meter, (7) continuous inspection of tinplate by light reflection, (8) visual inspection of hot rolls by telescope eyepiece, (9) combustion control of open hearth by excess-air and waste-gas analysis, (10) power input controller for an arc furnace, (11) roof temperature control by rate of temperature range, (12) automatic forging, (13) automatic gage control for rolling mills, etc.

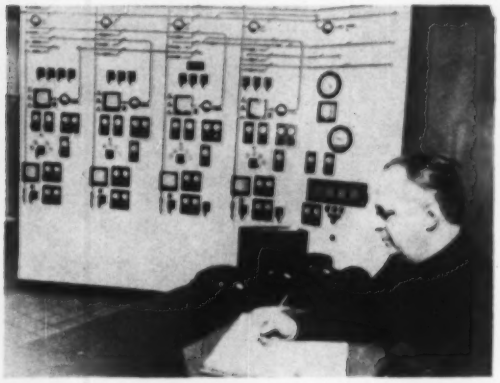
Marion, Dixie and Joyce

LAJOLLA, CALIF.—While touring through the delightful modern plant of Daystrom Systems in LaJolla, your editors noted that the names of girls were prominently displayed above each project area. We asked if each project was named after a girl for the same reason that hurricanes are—but found that Chal Jones had a much better reason and much better names. Each Daystrom project is not only named but dedicated to a feminine worker at Daystrom, (selected by chance) in order to personalize the project. This reminds all the workers that each one on the project has a personal stake in the accuracy and precision and care with which every wire and component is assembled and handled. "This personalization of inanimate projects has much to do with the phenomenal record of accuracy and error-free operation achieved by our units," says Chalmer Jones, General Manager of Daystrom Systems. Some of the girls selected to date, and their projects, include:

Dixie—Louisiana Power & Light (Sterlington)
Mary Beth—Kansas City Power & Light (Gordon Evans Station)
Enice—Gulf States Utilities (Willow Glen)
Jewel—Universal Oil Products (U.O.P.)
Rae—Public Service Co. of Arizona (Tape-to-Tape Converter)
Georgia—Remington Rand (Tape-to-Tape Converter)
Marion—David Taylor Model Basin Spectrum Analyzer
Merlene—Great Lakes Steel Co.
Joyce—Westinghouse Bettis
Florence—Union Carbide
Eileen—David Taylor Model Basin
Vauda—David Taylor Model Basin

Controls Split Wind in Steel Mill

PITTSBURGH, PA.—Split-wind blowing systems where one or more blowers supply blast air to two or more blast furnaces are becoming prevalent in steel mills.



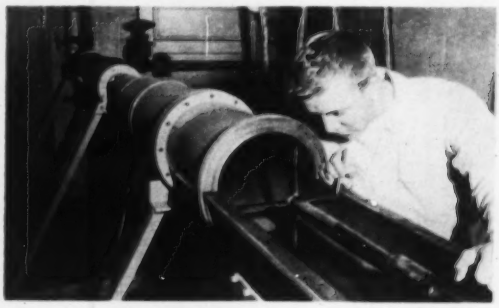
Centralized control is provided by a graphic panel where (1) position of all control- and shut-off-valves is shown, (2) flow and pressures to each furnace, as well as those developed at each blower are indicated and recorded. The motorized electric shut-off valves can be remotely, manually operated from here, and furnace set point and manifold pressure can be changed by the operator.

Installation of the controls was planned and executed by Hagan Chemicals & Controls, Inc., Hagan Center, Pittsburgh 30, Pa.

FOR MORE INFORMATION CIRCLE 180 ON READER-SERVICE CARD

Tunnel Tubing

ELK RIVER, MINN.—FluiDyne engineer C. W. Landgraf points to a "rake" equipped with manometer lines of Type 304 stainless-steel tubing supplied by Superior Tube Company, Norristown, Pa. Tubing is connected to



manometer board shown. Installed in the Mach 7 hypersonic test tunnel at the FluiDyne Engineering Corporation's research laboratory at Elk River, Minn., the tubing senses pressures at various points during tunnel calibration. Type 304 was found to be more reliable than brass tubing for this service.

FOR MORE INFORMATION CIRCLE 181 ON READER-SERVICE CARD

Latest news about the 609

In 1960... Four ISI 609's now serving the process and power industries. Four more to be delivered this year for Chemical process analysis and production control... Natural Gas dispatching... Electrical Utility power generation

Why customers are buying the practical 609 INFORMATION AND COMPUTER SYSTEM

The 609 is exceptionally versatile—You get simultaneous on-line automatic control and off-line analytical computation. Multiple programming is a practical reality in the 609 through automatic priority interrupt.

Expandable System—Optional disc memory provides additional quick access working storage available in modules of various word capacities.

On-Line Control Unit provides fast (2.80ms) multiplication and square root—contains input-output controls for on-line communication with the process to be monitored and controlled.

Index Registers—An extra digit in *every* instruction word makes it possible for every command to function as an index register.

Both the operator and the computer engineer can use this advanced system. A direct, plain English Input Control Panel enables the operator to change or read out any process data constants or scanned variables.

ISI

BEST INVESTMENT IN THE CONTROL COMPUTER FIELD

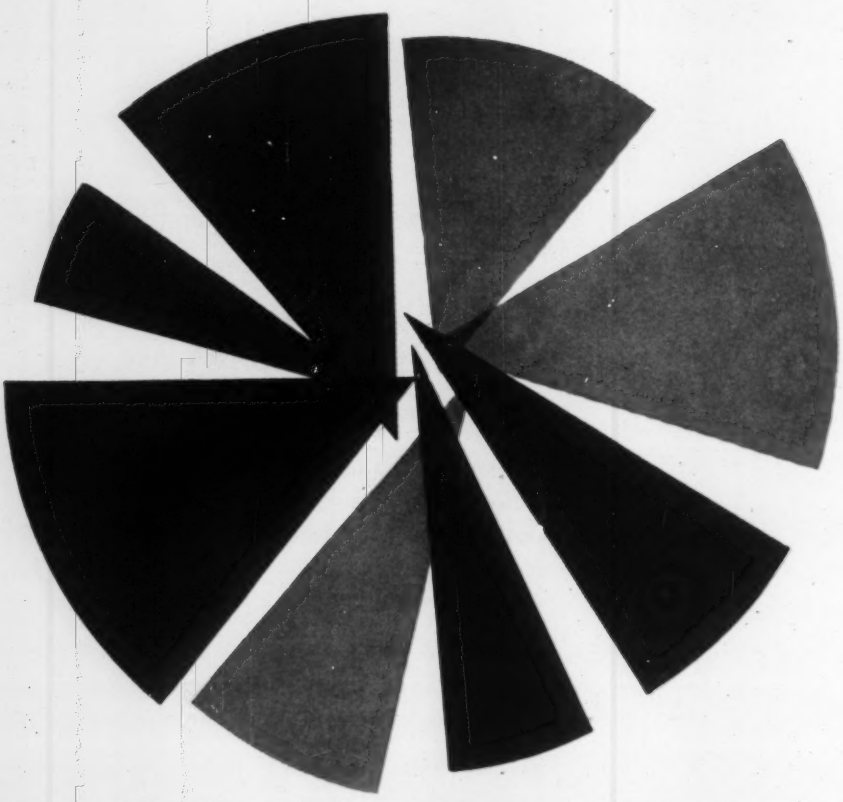
The solid state, reliable 609 is applied to your objectives by ISI—a company with 10 years of experience in engineering practical data systems for the power and process industries.

Write J. Davis, V. P. for Technical Bulletin 609-100A

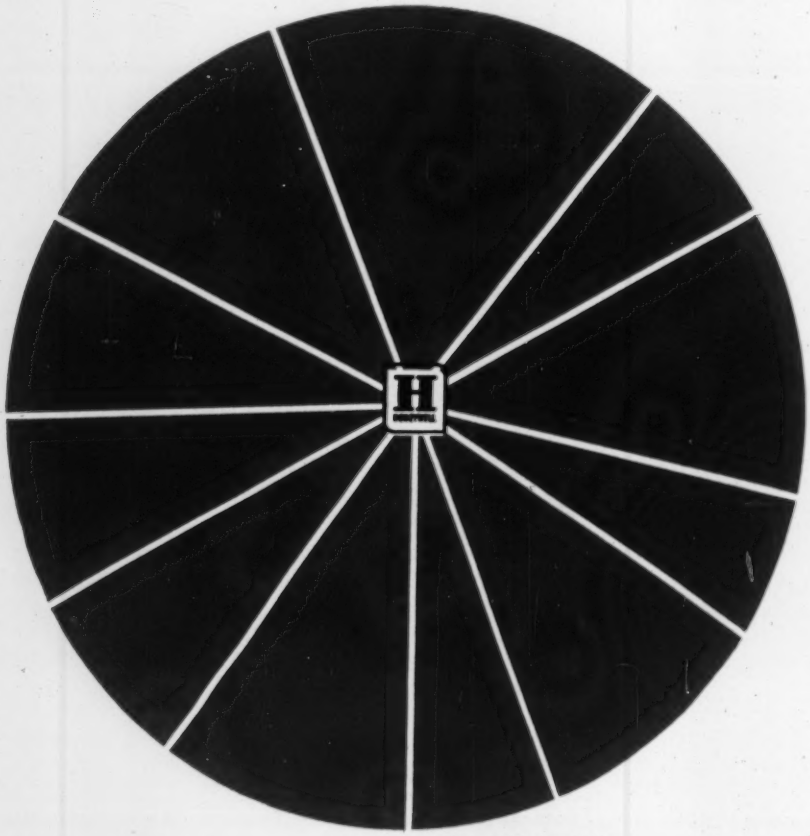
INFORMATION SYSTEMS, INC.

COMPUTER DIVISION ■ 10131 National Blvd., Los Angeles 34, Calif.

CIRCLE 22 ON READER-SERVICE CARD



YOUR PLANT'S CONTROL SYSTEM—HYBRID OR HONEYWELL?



CIRCLE 23 ON READER-SERVICE CARD

The answer can be important to you. True, you can combine several makes of instruments into a system and get adequate results. But you usually pay a penalty for hybrid systems. There's the burden of responsibility for engineering and maintaining the system. There's the question of whether it will do what you want it to. There's the problem of modifying various makes of components to work together. And there's the inconvenience of buying instruments and spare parts from several suppliers instead of one.

Single-Source Responsibility. You avoid all of this with an all-Honeywell data processing or automatic control system. All components, from primary measuring elements to final controls, are supplied by Honeywell. If your requirements call for an analog or digital computer, Honeywell can supply it. From our systems engineers you get the advantage of experience gathered over 75 years of measurement and control work in scientific, military and industrial operations. And Honeywell takes full responsibility for the system, from initial planning through installation and startup, and even including maintenance.

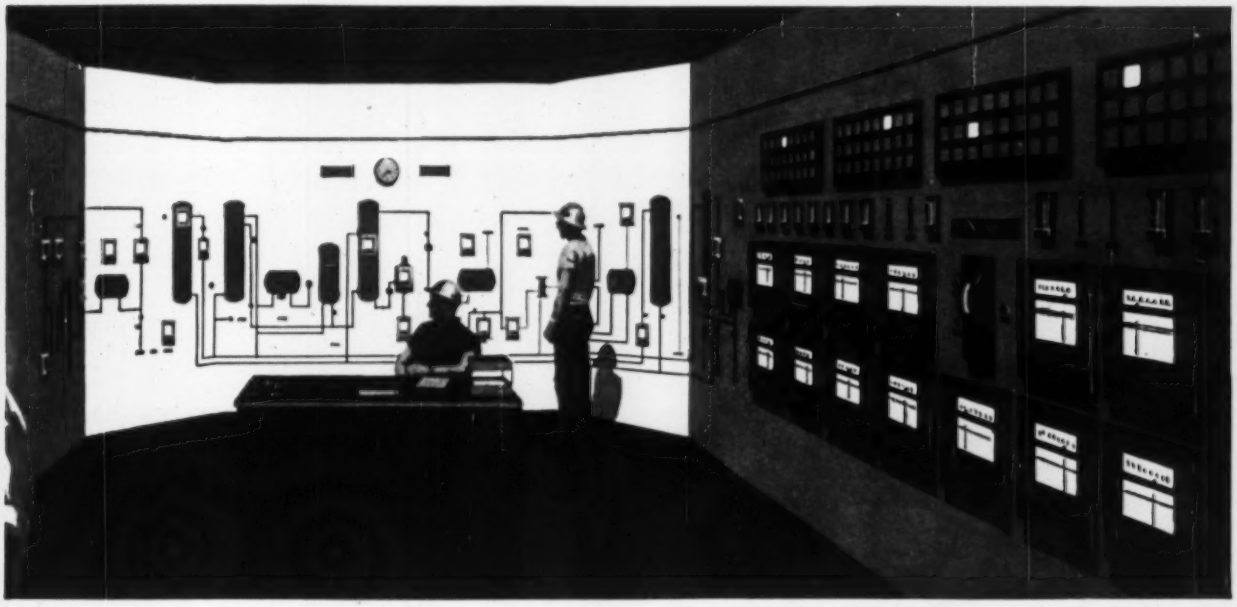
Conserve Your Working Capital. You can conserve working capital by leasing a Honeywell system from one to five years, paying for it as you use it. Because you lease at today's prices, you're protected against possible future price increases. Because you deal *only* with Honeywell, you needn't worry about long negotiations with third parties.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa. In Canada, Honeywell Controls, Ltd., Toronto 17, Ontario.

75th YEAR
PIONEERING THE FUTURE

Honeywell

First in Control
SINCE 1885



CIRCLE 23 ON READER-SERVICE CARD

FIRST AND FOREMOST

the dependable

Dillon
DYNAMOMETER

Measures tensile, compression, torque or weight with an accuracy of 2% plus or minus full range. Calibrated directly in pounds. 15 *different* capacities from as low as 0-500 lbs. up to as high as 0-200,000 lbs. Equipped with maximum pointer, shackles and pins, safety glass crystal. 5" or 10" diameter dials optional. Overload protected. Extremely rugged. Priced LOW to meet average shop budget.

D28

Announcing...

DILLON DYNAMOMETER
Design Manual

Published specifically for engineers, foremen, supervisors, etc., Dillon Dynamometer Design Manual illustrates and thoroughly describes almost 100 typical installations of traction Dynamometers in *all* types of industries. Measures 8½" x 11". Stiff covers. All illustrations full size. A *must* for any engineering library. Cost over $5.00 per copy to produce. Will be sent FREE to those writing for the Dillon Dynamometer story. A copy of Dillon's instrument catalog describing testing machines, thermometers, scales, etc. will be included.

D-28

W. C. Dillon & CO. INC.
14584 Keswick Street
Van Nuys 13, Calif.

CIRCLE 24 ON READER-SERVICE CARD

IGS STOCK REPORT

Further information may be obtained from the Research Department, Bache & Co., 36 Wall Street, New York 5, N. Y.

NEW YORK STOCK EXCHANGE

PRICE RANGE FOR 1960 THRU AUGUST 18, 1960

	High	Low	Price As Of 8/18/60
ACF Industries	52	41 1/8	46 1/8
Aeroquip Corp.	40 5/8	26 1/2	29
Allis Chalmers	40	26 3/8	27 3/4
American Chain & Cable	51 3/4	44	48 1/4 Bid
			49 1/4 Asked
Amer. Mach. & Foundry	74 3/4	49 1/2	69
Amer. Mach. & Metals	58 1/4	38 1/4	42
American Optical	67	43 1/4	62 1/8
Amer. Tel. & Tel.	96 1/8	79 7/8	90
Aspen Corp.	42 1/4	30	33
Bausch & Lomb Optical	58 7/8	34 1/2	46 3/4
Beckman Instruments	103 1/2	62 1/2	93 1/2
Bell & Howell	57 1/2	37 5/8	48 3/4
Bendix Aviation	74 1/2	57 1/2	67 3/4
Boeing Airplane	35	23	33 5/8
Bullard	17 7/8	12	14
Bulova Watch	22 7/8	14 1/8	21 1/4
Burroughs	40 3/8	28 3/4	36 3/8
Carborundum	49 7/8	41 1/4	44 1/8
Cinn. Milling Machine	38 1/2	26 3/4	30
Clevite	71 3/4	42	62 1/2
Columbia Broadcasting Sys.	45 1/4	36 5/8	41 5/8
Consol. Electronics	60 3/4	42 1/4	55 7/8
Corning Glass	186	124	164
Curtiss Wright	31 1/8	16 1/2	18 5/8
Cutler-Hammer	96	75	82
Dayatron	49 3/8	35 3/4	39
Douglas Aircraft	42 3/8	27	33 1/2
Eastman Kodak	136 1/4	94	121 7/8
Eaton Mfg.	46 7/8	30 1/4	33 1/2
Electric Auto-Lite	54 1/2	44 1/2	50
Elgin Watch	19 1/8	11 1/2	15 3/4
Emerson Electric (new)	50	33	45 5/8
Food Mach. & Chem.	57 1/2	44 1/2	53 3/8
Garrett	54 7/8	42 1/8	50 1/2
General Controls	29 5/8	18 1/2	21
General Dynamics	53 3/8	38	44 1/2
General Electric	99 7/8	79	81 7/8
General Instruments	50 3/8	22 1/2	43
General Mills	31	23 7/8	28 1/4
Gen. Precision Equip.	66 5/8	44 1/4	55 5/8
Gen. Railway Signal	36 7/8	27 1/2	29 3/8
Gen. Tel. & Elect. (new)	34 1/8	23	28 5/8
General Time (new)	33 1/8	16 5/8	20 1/2
General Tire & Rubber	81 3/8	50 7/8	56 1/4
International Bus. Mach.	541	407 1/4	541
International Resistance	41 5/8	18 1/4	34 1/8
Internat'l. Tel. & Tel.	46 3/4	32	42
I-T-E Circuit Breaker	44 1/4	19 7/8	23
Lear Inc.	23 1/2	13 5/8	19 1/2
Litton Industries	96	57 5/8	88 1/8
Lockheed Aircraft	32 7/8	18 5/8	24 3/8
Magnavox	55	32 3/4	49 3/4
Mallory	50 1/4	40 3/8	42 1/2
Minneapolis-Honeywell	178 3/4	123 5/8	151
Minnesota Mining & Mfg.	88	65	74 3/4
Motorola (new)	98	75 1/8	83 1/2
National Acme	54 3/4	42 1/4	45
National Cash Register	70 7/8	54 5/8	58 3/4
Neptune Meter	34 3/8	26 3/4	26 1/4
North American Aviation	44 1/8	29 5/8	43 1/4
Northrop Aircraft	39 7/8	24 3/4	39 7/8
Otis Elevator	58 1/2	36 3/4	54 1/2
Philco Corp.	38 1/4	23 3/4	24 3/4
Radio Corp. of America	78 3/8	58	62 1/8
Raytheon Mfg.	53 3/8	35 1/2	38 3/4
Reliance Electric	68 5/8	47 3/4	56 1/2
Rheem Mfg.	28 7/8	15 5/8	18 3/4
Robertshaw Fulton	55	36 1/2	39 3/4
Royal Mc Bee	21 3/8	13 1/4	14 1/4
Sangamo Electric	23 1/2	16	16 5/8
Siegler Corp.	43	29 1/4	35
Sperry Rand	26 1/4	20 1/8	21 1/2
Square D	37 7/8	25 1/2	29 1/8
Standard Kollsman	30 1/2	12 5/8	24 1/2
Starrett (L.S.)	20	16	18 1/4 Bid
			18 1/2 Asked
Stewart-Warner	33 1/2	23	28 1/2
Talautograph	10 1/4	6 7/8	8 1/8
Texas Instruments	256 1/4	154	224 1/2
Thompson-Ramo-Wooldridge	67 1/2	46 7/8	58 3/4
Tung-Sol Electric	40 1/2	28	34 3/4
Underwood Corp.	54 1/2	34 3/4	50 1/4
Union Carbide Corp.	148 1/2	113 1/2	119
United Shoe Machinery	64 3/8	50	58 3/8
Varian Associates	67 1/2	39 3/4	56
Wallace & Tiernan	63	41	62
Western Union	57	41 3/4	46 7/8
Westinghouse Air Brake	32 5/8	25 1/8	26 5/8
Westinghouse Electric	65	45 1/2	55 1/8
Worthington Corp.	66	45	49 1/4

(1) Not Traded - Bid & Asked

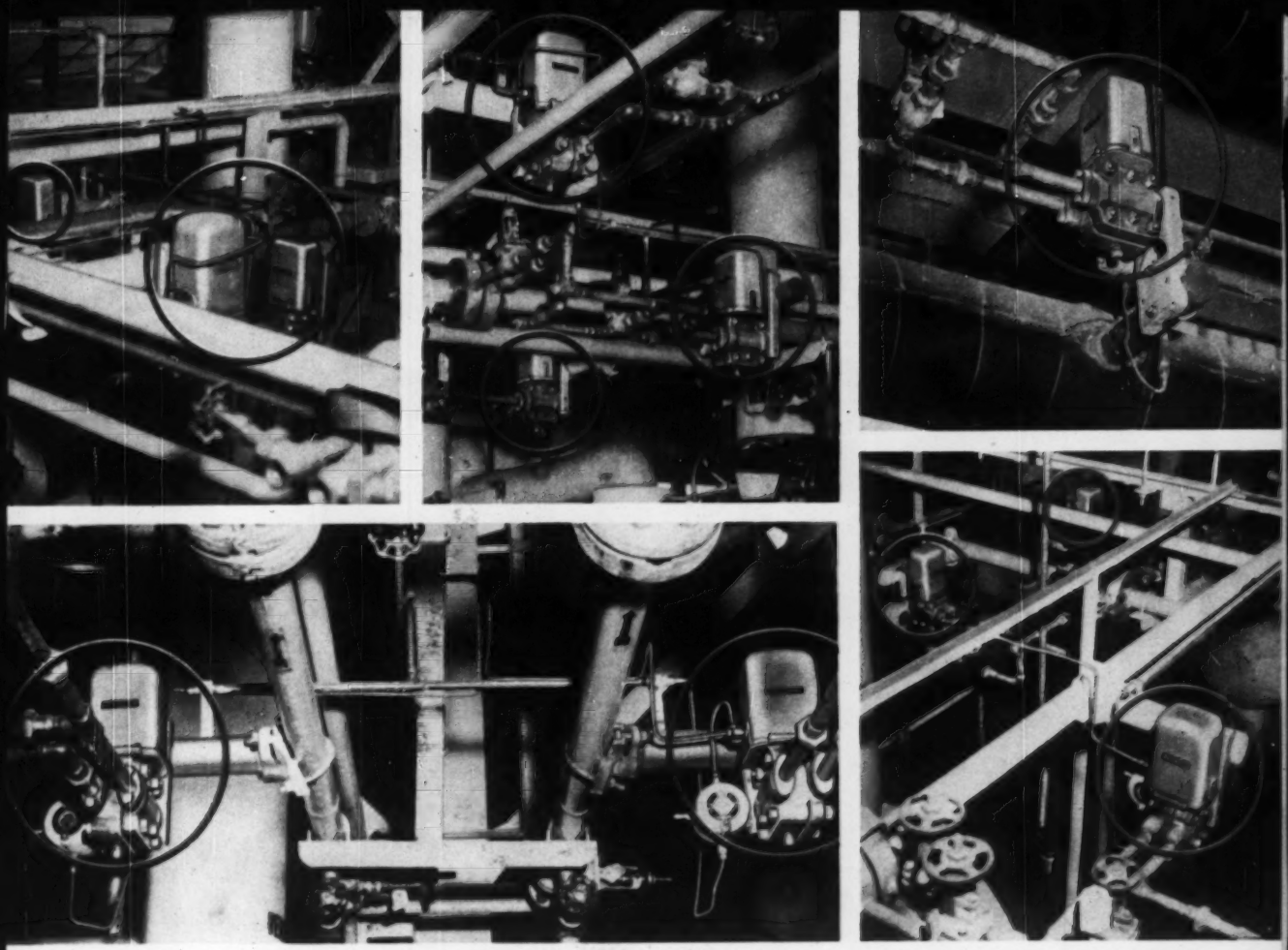
These prices and price ranges are given as printed in the Wall Street Journal

AMERICAN STOCK EXCHANGE

PRICE RANGE 1960 THRU AUGUST 18, 1960

	High	Low	Price As Of 8/18/60
American Meter	52	44	43 3/4 Bid
			44 1/4 Asked
Aro Equipment	25 1/4	19	24 1/2
Barry Controls "B"	25 1/2	16 1/4	19 3/4
Belock Instruments	25 3/8	13 1/8	21 7/8
Bencus Watch	7 3/4	5 3/8	7
Breeze Corp.	8 5/8	4 5/8	4 7/8
Clark Controller	23 5/8	20	20 5/8
Clarostat Mfg.	16 3/8	9 7/8	13 3/8
Clary Corp.	11 1/2	6 3/4	9 5/8
Cubic Corp.	69	48 1/2	63 1/2
Dynamics Corp. of Amer.	13 1/4	9	9 7/8

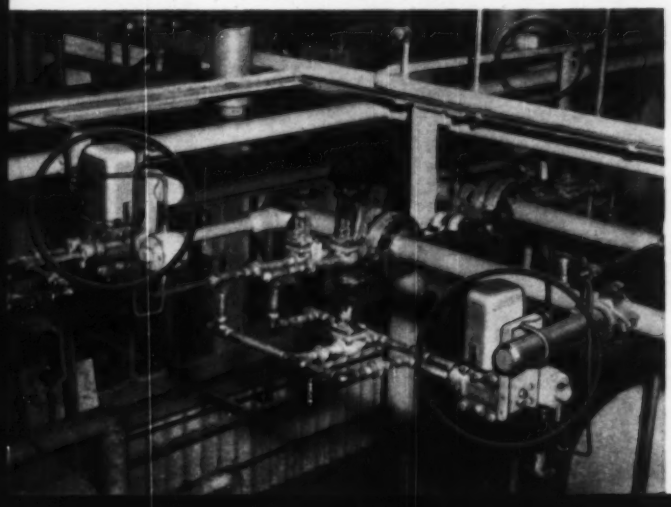
Continued on page 1470



A few of the more than 100 Foxboro d/p Cell Flow Transmitters installed at Missouri Chemical Works of Hercules Powder Company, Louisiana, Missouri.

Hercules' Missouri Chemical Works reports:

"Foxboro d/p Cells* always accurate . . . never need re-calibration"



At Hercules Powder Company's 540-acre Missouri Chemical Works, there are over 100 Foxboro d/p Cell Transmitters in operation today — providing high-speed flow measurement and transmission throughout the ammonia, formaldehyde, methanol and pentaerythritol plants.

"Reliability is the big thing," according to Hercules instrument engineer J. J. VanSchaik. "We can install a Foxboro d/p Cell and forget it. Once it's calibrated, we know it'll stay that way. We never even stock spare parts."

Hercules especially likes the Foxboro d/p Cell for flow control. "Gives us closer control," says instrument engineer H. McCombie. "Eliminates one possible source of inaccuracy and maintenance trouble in the control loop."

Let Hercules' experience be your experience — with Foxboro d/p Cell Transmitters as the basis for your control system. Write for full details in Bulletin 13-11A. **The Foxboro Company, 469 Neponset Avenue, Foxboro, Massachusetts.**

*Reg. U. S. Pat. Off.

FOXBORO
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FIRST IN FLOW

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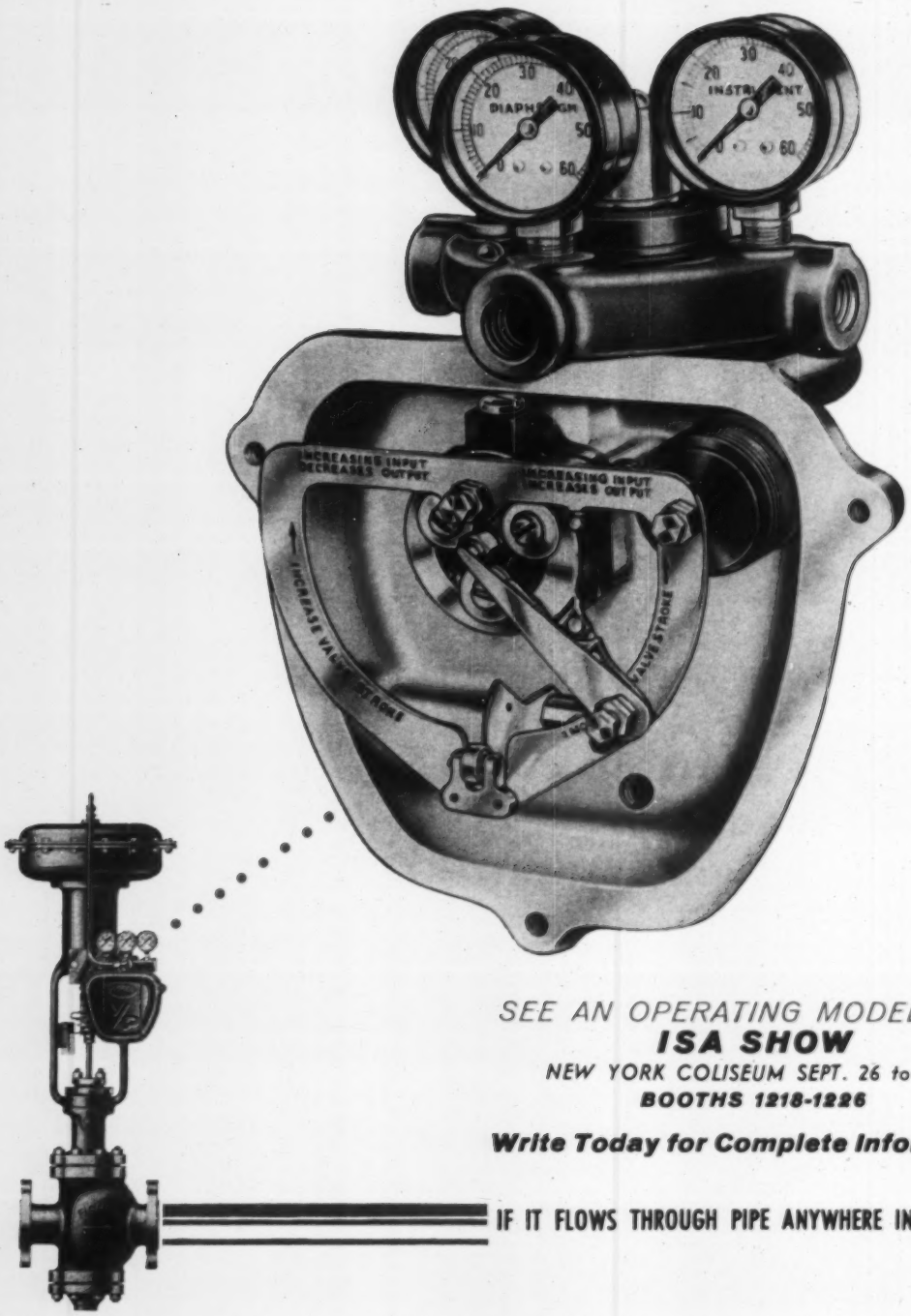

SEE AN OPERATING MODEL at the

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BOOTHS 1218-1226

Write Today for Complete Information

IF IT FLOWS THROUGH PIPE ANYWHERE IN THE WORLD...

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FISHER Type 3560 VALVE POSITIONER V/P

Assured product performance through DYNAMIC ANALYSIS engineering

Application of mathematical techniques of design to pressure control systems has enabled Fisher to completely eliminate guesswork in the development of the new V/P valve positioner. It has provided the V/P with the following combination of characteristics and performance ... unobtainable in any other type of valve positioner.

SMALL AND COMPACT... only 6⅜" wide and 8¾" high (with gauges).

CONVENIENT ADJUSTMENT... valve stroke and zero adjustment readily accessible and easy to make.

SPLIT RANGE... no parts change whatsoever is required for split range operation.

EASILY REVERSIBLE... reversed by simply moving flapper arm from one beam quadrant to the opposite quadrant.

CHARACTERIZED CAMS... offer wide flexibility in valve characteristics.

PERFORMANCE DATA

Hysteresis, (Average)....0.0012"	Stroking Speed....0.37 in/sec.
Linearity....as required. Change cams to obtain desired characteristics	Air Consumption....10 s.c.f.h.
Sensitivity....0.14 p.s.i.	Break Frequency 5% of instrument pressure range....3.0 cps
Resolution Sensitivity....0.002 p.s.i.	Break Frequency 3% of instrument pressure range....4.6 cps
Repeatability....0.0003"	

The above performance data was taken from laboratory tests on a type 657 diaphragm actuator, Size 40, with 1½" travel. Instrument range 3 to 15 p.s.i.

FISHER GOVERNOR COMPANY

Marshalltown, Iowa / Woodstock, Ontario / Rochester, England

...CHANCES ARE IT'S CONTROLLED BY

FISHER® Controls

SINCE 1880

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PHILADELPHIA
THERMAL CONTROLS AND THERMOMETERS

Specify! THE BEST!

A half century of experience is back of every instrument we make. You get assured accuracy and long dependable performance when you specify "Philadelphia." Our specialized staff will be glad to discuss your problem in our field.

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HIGH FREQUENCY INDUCTION
HEATING EQUIPMENT
For Hardening • Annealing • Soldering
Brazing • Zone Refining • Crystal Growing

ELECTRONIC TUBE GENERATORS:
1 kw; 2½ kw; 5 kw; 10 kw; 20 kw; 30 kw; 50 kw; 75 kw; 100 kw.

SPARK GAP CONVERTERS:
2 kw; 4 kw; 7½ kw; 15 kw; 30 kw.

WRITE FOR THE NEW LEPEL CATALOG 36 illustrated pages of valuable information.

LepeL HIGH FREQUENCY LABORATORIES, INC.
55th ST. & 37th AVE., WOODSIDE 77, N. Y.

CIRCLE 28 ON READER-SERVICE CARD

AMERICAN STOCK EXCHANGE

continued from page 1466

El-Tronics	1 7/8	1 1/8	1 1/2
Electronics Corp. of Amer.	19 1/2	8 1/8	12 3/8
Fairchild Camera & Instrument	200 1/2	110 1/4	194 1/2
General Transistor	33 1/4	10 5/8	29 7/8
Giannini Controls	61 1/2	41 3/4	58
Globe-Union	34 3/4	25	27
Haseltine Corp.	31 1/2	23	26 1/2
Loral-Electronics	102 1/4	34 5/8	101
National Research	23 1/8	14 7/8	18
New Haven Clock	2 7/8	1 1/4	1 7/8
Nuclear Corp. of Amer.	5	2 1/8	4 3/8
Philips Electronics, Inc.	46 7/8	31 1/2	42
Pneumatic Scale	59 3/4	39 1/4	39 1/2 Bid 41 3/4 Asked
Polarad Electronics (new)	36 5/8	23 5/8	30 1/4
Servo Corp. of Amer.	24 1/2	14 1/4	16
Servomechanisms	16	8 1/8	9 7/8
Statham Instruments Inc.	40 1/4	27 1/8	37 1/4
Textron Electronics	18 3/4	11 1/4	14
Victoreen Instrument Co.	15 1/2	9 3/4	14 5/8
Waltham Prec. Instr. Co.	3 1/2	2	2 1/4

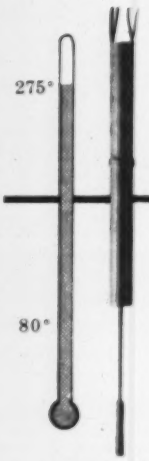
(1) Not Traded - Bid & Asked

These prices and price ranges are given as printed in the Wall Street Journal.

Dumont Labs. merged with Fairchild Camera.

OVER THE COUNTER

	Quotation As of August 18, 1960 Bid	Asked
Aerovox Corp.	9 1/2	10 1/4
Argus Corporation	30	30 3/4
Black Sivalls & Bryson Inc.	14 1/4	15
Eitel Mc Cullough	26	26 5/8
Electro Instruments	39	40 1/2
Electronics Associates	28 1/2	29 1/4
Erie Resistor Corporation	8 1/2	8 3/4
Fisher Governor Co.	17 1/2	18
Foxboro Company (new)	44	46
Hagan Chemicals & Controls	43	44
Industro Transistor	8 1/2	9
Liquidometer Corp.	19 1/2	20 1/2
W. L. Maxson	8 3/8	8 7/8
Penn Controls	22	23
Speer Carbon, Inc.	23	24
Sprague Electric	56 3/4	57 1/2
Taylor Instruments	82	86
Telechrome Mfg. Corp.	13	13 3/4
Telecomputing Corp.	8 1/2	8 5/8
Vitro Corp. of Amer.	14 5/8	15



Temperature Compensated
TRANSDUCERS
FOR 400 CPS SERVO SYSTEMS

Output for a given position changes only 1% over a range from 80° to 275° F. These extremely rugged units are widely used as feedback transducers in missile and aircraft actuators.

LINEAR DIFFERENTIAL TRANSFORMER
Model GM-8013

Input: 26V 400 CPS
Stroke: ±.7"
Linearity: 1%
Output: 8 Volt/inch @ 26V 400 CPS input

Change in gain over temperature range: .005%/°F.
Temperature range: -65°F to +300°F
Vibration: To 35 g's, to 2000 CPS
Housing Length: 4"
Housing Diameter: ¾"

linear displacement • angular position • velocity • torque force • pressure

EXPECT MORE FROM VINSON SYSTEMS

Phones: TR 3-3510, ST 6-7210 • 8044 Woodley Ave., Van Nuys, California

Your inquiry will receive an immediate reply from engineers experienced in the design and application of transducers for the solution of measurement and control problems.

CIRCLE 29 ON READER-SERVICE CARD

CIRCLE 30 ON READER-SERVICE CARD →

When you discuss solenoid valve requirements with an ASCO engineer, you benefit from the design and development experience of half a century. The ASCO specialist can recommend the right valve for your needs because ASCO pioneering has brought about the thousands of types of solenoid valves now available:

Two-way valves in pipe sizes from ⅛" to 8"—for temperatures from -350°F to 600°F—for pressures to 5000 p.s.i.

Three-way valves in pipe sizes from ⅛" to 2"—for temperatures from -350°F to 600°F—for pressures to 1000 p.s.i.

Four-way valves in pipe sizes from ¼" to 1½"—for temperatures from -65°F to 212°F—for pressures to 750 p.s.i.—poppet or slide type.

And ASCO can supply you with standard, explosion-proof or water tight enclosures—Class A and Class H coils—a wide range of body materials including cast iron, brass, bronze and stainless steel. Or trade on ASCO experience and have one of our engineers call.

New! Catalog No. 202 covers the ASCO line of Solenoid Valves. Write for your copy today.

For Immediate Delivery...

World's largest stock of Solenoid Valves. A complete Solenoid Valve Stock List will be sent to you with your copy of Catalog No. 202.

Whatever the crucial factor in your flow control applications—reliability, compactness, high cycling rate—there is an ASCO valve that meets your need.

ASCO Valves

ASCO

Automatic Switch Co. 52-L HANOVER RD., FLORHAM PARK, N. J., FRONTIER 7-4600

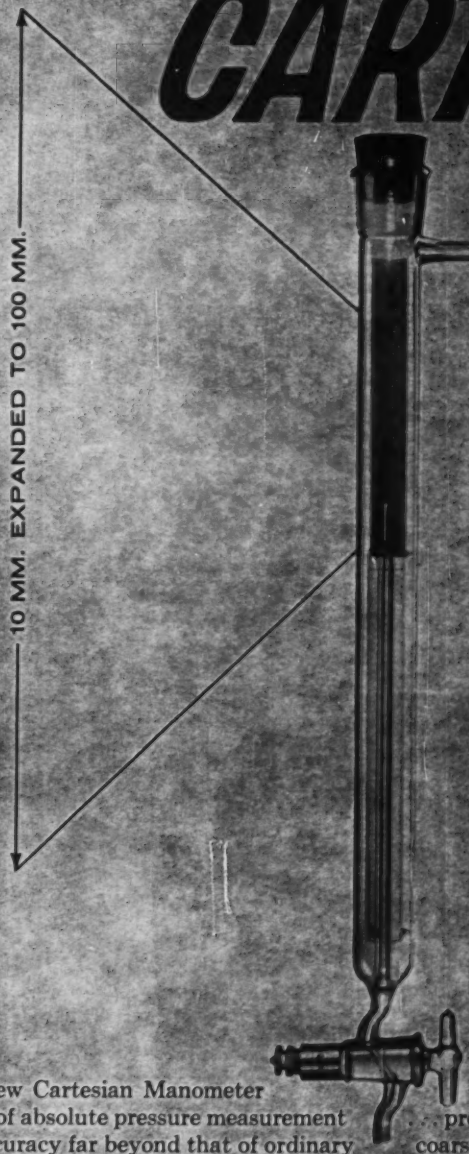
AUTOMATIC TRANSFER SWITCHES • SOLENOID VALVES • ELECTROMAGNETIC CONTROL

CIRCLE 30 ON READER-SERVICE CARD

Now... Read 0-10 mm. Pressure Measurements Easily on a Convenient, Accurate 100 mm. Long Scale!

CARTESIAN MANOMETER

...for both absolute and differential readings



RANGE: 0-10 mm. Hg.

GRADUATION: 0.1 mm. Hg.

ACCURACY: 1% of full scale

CONSTRUCTION: All glass

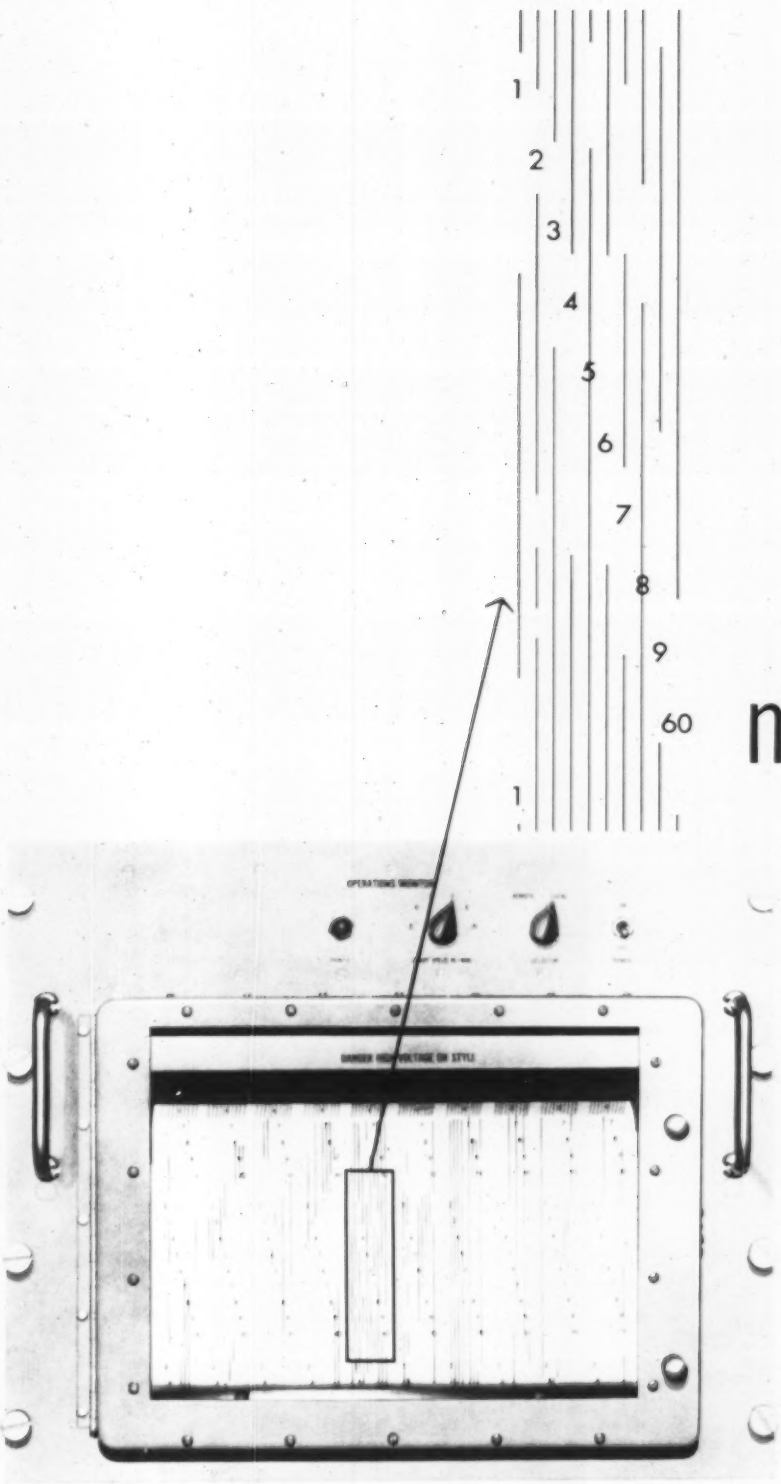
This new Cartesian Manometer simplifies readings in the difficult 0-10 mm. region of absolute pressure measurement . . . providing convenience no McLeod gauge can match, and accuracy far beyond that of ordinary coarse manometers. ■ By using a 100 mm. long scale, the Cartesian Manometer magnifies 0-10 mm. pressure measurements by a factor of 10, making exact readings far more readily obtainable. ■ The Cartesian Manometer employs a stopcock for easy conversion from differential to absolute readings. The instrument can be read continuously and directly. ■ Because of its ease of use, the Cartesian Manometer is particularly valuable for vacuum distillations, oven drying, accurate differential pressure measurement, flow measurement, and a host of other applications. ■ **T10707 . . . Cartesian Manometer complete and ready for use, but without mercury . . . $29.90 ea.**

The EMIL GREINER Co.

20-26 North Moore St., Dept. 423 New York 13, N. Y.

CIRCLE 31 ON READER-SERVICE CARD

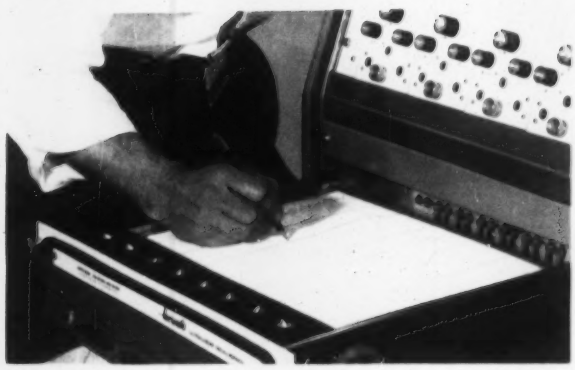
CIRCLE 32 ON READER-SERVICE CARD→

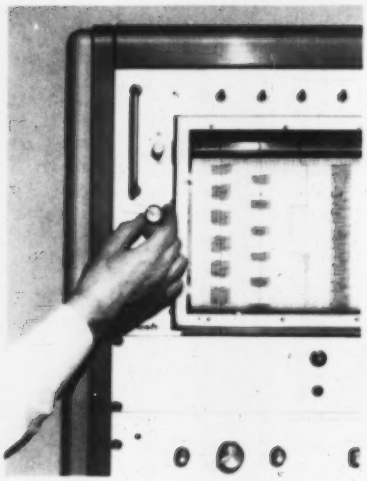


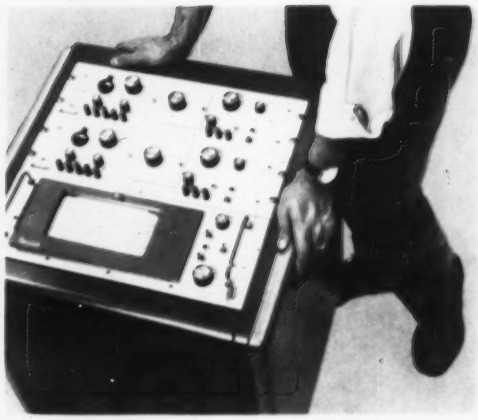
insight at 4 milliseconds

recorded with Brush operations monitors. Multiple high-speed events are reported in writing within 4 milliseconds of occurrence—to establish the basis for split-second, million dollar decisions necessary in today's complex control systems. Up to 120 separate "on-off" event signals are monitored and permanently recorded on a chart only 12" wide. Fixed-stylus electric writing provides sharp, reproducible traces of uniform clarity. Chart speeds from one to 250 mm/sec permit a precise interpretation of all events, with resolution up to 500 signal changes per second. For military or industrial analysis and control, no direct writing recording system can match the capabilities of Brush Operations Monitors. Write today for complete specifications and application data.

brush INSTRUMENTS
DIVISION OF
37TH AND PERKINS CLEVITE CORPORATION CLEVELAND 14, OHIO







in direct

writing

systems

only Brush eliminates compromise

Avoid a "second best" choice. Get exactly what you need. Only Brush permits selection of . . . **Writing Method** . . . ink, electric or thermal . . . **Trace Presentation** . . . curvilinear or rectilinear . . . **Configuration** . . . vertical or horizontal, rack mounted or portable models. Also . . . chart speeds from 50″/sec to 10″/day . . . functionally designed control panels . . . readily accessible components for fast inspection, simple adjustment . . . complete, easy to understand operating manuals. Get the industry's most advanced design concepts. You never need compromise when you specify Brush. Complete information at your request.

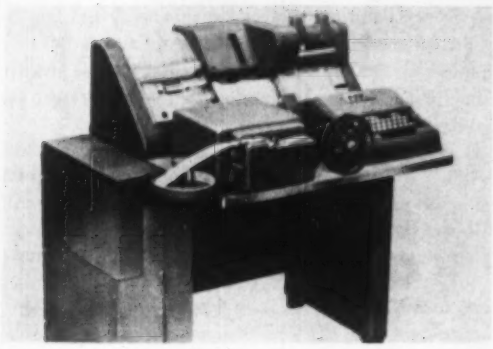
brush INSTRUMENTS

DIVISION OF CLEVITE CORPORATION

37TH AND PERKINS CLEVELAND 14, OHIO

I&CS BRIEFS

Universal Code-Tape-to-Card Converter



The C750 will convert 5, 6, 7 or 8 channel Tape—of any Code Structure—to IBM cards. Decoding from tape codes to IBM card codes is controlled entirely by wiring to the removable program plugboard. The C750 converts punched tape at maximum card punching speeds: 20 characters per second with the 024 Card Punch or 18 characters per second with the 026. Parity checking of both odd-bit tape code system, controlled by plugboard wiring, is standard feature of the C750 . . . (*From new 4-page bulletin, Systematics, a div. of General Transistor Corp., 118 South Catalina Ave., Redondo Beach, Calif.*)

FOR THIS LITERATURE CIRCLE 188 ON READER-SERVICE CARD

"Computerese"

"Computerese" is a whole new language conceived by the computer engineers over the past several years . . .

Arithmetic Unit: The part of a computer that performs arithmetic and *logical operations*. In the case of you and your desk calculator, the latter is comparable to the computer's arithmetic unit . . .

Flip-Flop: A device or circuit with two stable states. The circuit remains in either state until the application of a signal causes it to change . . .

Gate: A circuit with one output and many inputs, designed so that the output is energized only when certain input conditions are met. They include *And Gates* and *Or Gates*. An "*And Gate*" is one whose output is energized only when all of the inputs are energized . . . A "*Or Gate*" is one whose output is energized when one or more of the inputs are energized . . .

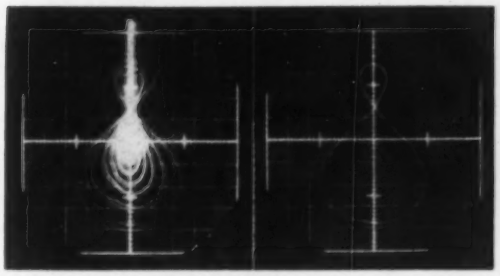
Mnemonic Code: *Instructions* for a computer written in a form which is easy for the programmer to remember, but which must later be converted into machine language.

(*From new 24-page pocket-size booklet with the same title, Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Phila. 44, Pa.*)

FOR THIS LITERATURE CIRCLE 189 ON READER-SERVICE CARD

←——CIRCLE 33 ON READER-SERVICE CARD

Low-Frequency Oscilloscope

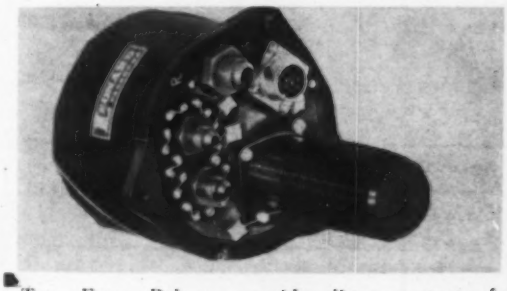


The 401-B has identical, calibrated, high-gain amplifiers. Manipulation of a few front panel controls puts the operator in charge of the most versatile, accurate plotting and measuring device in the low-frequency field . . . A radically new cathode-ray tube operates at 5000 volts, providing finer spot size.

A positive unblanking gate is available internally to intensify the display only during the forward sweep . . . For example, if the strain *vs* velocity of a vibrating beam were to be picked up by the appropriate transducers, the signal applied to both axes would approximate damped sinusoidal waves in appearance. The full CRT display would be rather meaningless (left photo). If, however, a particular cycle of the waveforms on each axis were desired for observation of a single plot, the controls could be set so that only one selected trace would be visible (right photo)—the remainder of the signal remains below the threshold of visibility . . . (*From new 4-page bulletin, Allen B. Du Mont Labs., Inc., Clifton, N. J.*)

FOR THIS LITERATURE CIRCLE 190 ON READER-SERVICE CARD

Force-Balance Transducer

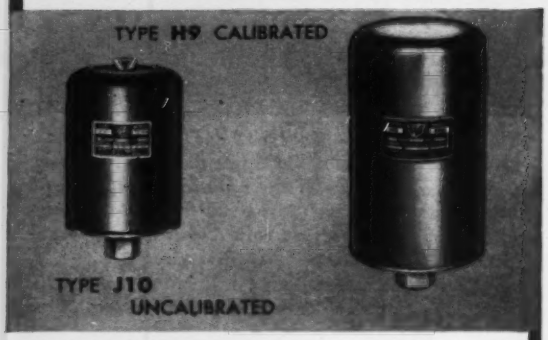


True Force Balance provides linear outputs for functions such a Mach No., indicated air speed, altitude, etc., without the use of cams, function gears, shunts, etc. . . . Isolates the force sensor from the output devices to minimize response to transients . . . Linear shaft output 10-1000 turns for full range. Multiple outputs—sufficient torque to drive combinations of potentiometers, synchros, code generators, ganged switches . . . Stepped outputs allow maximum use of recording resolution . . . Output resolution of 1400 steps per shaft rotation . . . Insensitive to vibration —10G to 2000 cps. Insensitive to accelerations up to 25 G's . . . (*From new 6-page short-form catalog, Wallace O. Leonard, Inc., 373 South Fair Oaks Ave., Pasadena, Calif.*)

FOR THIS LITERATURE CIRCLE 191 ON READER-SERVICE CARD

Sensitive H9 J10

PRESSURE and VACUUM CONTROLS



UNITED ELECTRIC's Type H9 and Type J10 controls are highly sensitive precision built pressure and vacuum controls designed for applications where close on-off differentials and constant repeatability are required. Type J10, being uncalibrated, is smaller and less expensive than Type H9 which is calibrated and has a knob & dial adjustment.

Specs:	
Various Ranges	H9-J10 — between 30" Hg. Vac. and 15 P.S.I.
Switch Differentials	H9 — ½ to 1 ±1/10" W.C. depending upon model. J10 — ¾ to 1 ±3/10" W.C. depending upon model.
Switch Ratings	Standardly 3 amps 115/230 A.C.
Switch Types	N.O., N.C., or Double throw, no neutral position.
Electrical Connections	Made to screw terminals on switches through clearance hole in enclosure.
Pressure Connections	One ¼" NPT pressure connection.
Size	H9 — 7" x 3⅜" dia. J10 — 6⅛" x 3⅜" dia.
Approximate Weight	H9 — 3 lbs. J10 — 2¾ lbs.

UNITED ELECTRIC *manufactures a complete line of temperature, pressure, and vacuum controls. For applications requiring custom-built units or modified standard units, call upon a UE application engineer for recommendations. Write for complete specification and pricing data on the Types H9 and J10. Similar data available on all other UE controls.*

U.E. United Electric Controls COMPANY
85 SCHOOL STREET WATERTOWN MASS.

CIRCLE 34 ON READER-SERVICE CARD

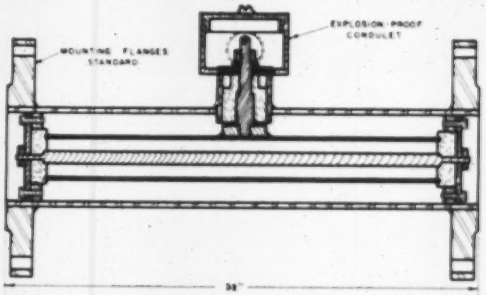
Washable Tracings on Drafting Film

The life span of an original tracing can be defined as the length of time it will produce legible prints . . . As line-background contrast diminishes (due to revisions, smudges, processing and filing) printability gradually drops off . . . With the advent of completely waterproof drafting base material—Dupont "Mylar" polyester film—a new possibility came to light. Given the proper drafting surface, it appeared that tracings might be made *washable* with soap and water. The engineered drawing surface of Herculene Drafting Film by K&E was designed with the long-range possibility in mind.

One further development was needed: a washable pencil line . . . A unique new pencil, called Duralar, made of plastic rather than graphite, which bonded with the Herculene surface, gave a drawing of amazing performance. Duralar lines were practically "smudge-proof." Soap and water could not wash the Duralar lines away . . . *(From new 4-page bulletin which includes sample of Herculene sheet and Duralar pencil, Keuffel & Esser Co., Adams and Third Sts., Hoboken, N. J.)*

FOR THIS LITERATURE CIRCLE 192 ON READER-SERVICE CARD

Capacitance Product Analyzer

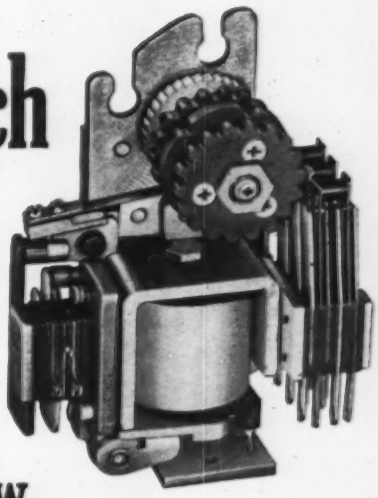


The complete CPA system consists of a probe with a coaxial cable connecting it to the Capacitance Balancing Unit. The output of the Capacitance Balance Unit is a mechanical shaft rotation which is used to drive a recorder pen; a telemeter transmitter; a pneumatic motion transmitter or a recorder *and* telemeter transmitter, depending upon the model selected.

The Capacitance Balance Unit consists of a crystal controlled oscillator operating at 3.5 megacycles with variable capacitor driven by a reversible electric motor integrated in a tuned plate circuit . . . The probe is a capacitor with the adjacent metal sections serving as the electrodes. This probe is inserted in a line containing the fluid to be measured or controlled. Almost all fluids have a different dielectric measurement. It is this dielectric difference which is measured as the fluids pass through the electrodes. Any change in the dielectric constant detunes the oscillator circuit which is in turn rebalanced by the variable capacitor in a servo-type network . . . *(From new 6-page Bulletin CP-758, Instruments, Inc., Box 556, Tulsa, Okla.)*

FOR THIS LITERATURE CIRCLE 193 ON READER-SERVICE CARD

Here's a Memory Switch You Won't Forget...



the New CLARE CAM-OPERATED type 200

offers a program control unit in reduced space and with simpler wiring. Actuating cams can be cut with a sequence of notches and lobes programmed to meet the contact switching desired. In addition, the Type 200 acts as a memory switch of unusual dependability and long life.

Operating life is measured in millions of steps. Over 30,000,000 operations have been logged with two cams and a 36-tooth ratchet; 10,000,000 with eight cams. Models are available with from 1 to 8 cams. Operating speed is 60 sps, self-interrupted, 30 sps, remote-impulsed.

The Type 200, as are all CLARE stepping switches, is available with a wide variety of hermetically sealed enclosures or dust covers to insure precise operation under all conditions.

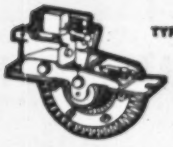
Production quantities available in late fall. Send for Bulletin CPC-7

C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: C. P. Clare Canada Ltd., P. O. Box 134, Downsview, Ontario. Cable Address: CLARELAY

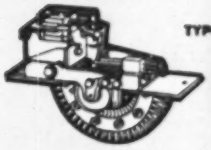
A FULL LINE OF CLARE STEPPING SWITCHES WITH MANY IMPROVED FEATURES

TYPE 210
Has 10 points, with as many as 120 contacts in twelve 10-point levels or four 30-point levels.

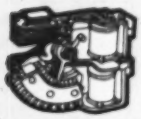
TYPE 211
Offers up to 132 contact points on twelve 11-point levels or four 33-point levels.



TYPE 20
Up to 480 contact points in twelve 40-point levels or 320 in sixteen 20-point levels.



TYPE 26
Up to 624 contact points in twelve 52-point levels or 416 in sixteen 26-point levels.



DIRECT DRIVE
Up to three 10-point levels, plus an off position.

Most complete Stepping Switch Catalog ever offered!

Complete data on construction features, circuitry, performance characteristics and application advantages of the entire CLARE line.

SEND FOR CATALOG 202 TODAY
FOR BULLETIN CPC-7, CIRCLE 35

CLARE

Relays and Related Control Components

FOR CATALOG 202, CIRCLE 176

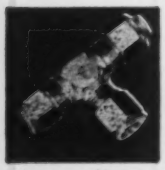
IMPERIAL
Engineering and Data File

IMPERIAL HI-SEAL AT A GLANCE...
. . . leakproof butt joints
shortest tube bends
saves space
holds pressures to 75,000 psi
temperatures to 1400 degrees
withstands extreme vibration

THE MOST VERSATILE TUBE FITTING YOU CAN USE!

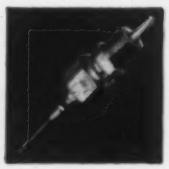
Now it's official. U. S. Patent No. 2,934,362 — just issued — recognizes seven claims for the only true butt joint tube fitting on the market. Imperial Hi-Seal is available in a variety of types that meet unusual pressure, temperature, vacuum and vibration conditions. And Hi-Seal allows bends closer to the fitting, making possible more compactness than ever before — saves space, saves tubing. All this *plus* make-and-break convenience.

Here are some of the variations that make Hi-Seal so versatile:



FILTER TEE. A highly efficient, easily installed blow-off type filter with sintered wire element. Standard filtration rating of 5 microns filters dust and impurities from gases for accurate instrument readings. For use in chromatograph analyzers and other gas analyzers, separation of water particles from oil and for protection of air activated instruments.

BRAZE-SEAL. Withstands pressures and temperatures that previously required a welded joint. Special alloy brazing rings for temperatures as high as 1400°F.



THERMOCOUPLE. Provides the advantages of higher pressures and temperatures, plus the positive make-up obtainable with Hi-Seal fittings. Also available with Teflon sleeve to permit readjustment to any depth.

DURA-TITE. The most effective port seal for tube fittings. No seeping — even at pressures up to 20,000 psi. Withstands higher temperatures than O-Rings.

Hi-Seal fittings are furnished in steel, stainless, brass and aluminum as stock items — also titanium, tantalum, Monel, Penton, Teflon and other metals and plastics to order. Available in a complete range of styles and sizes.

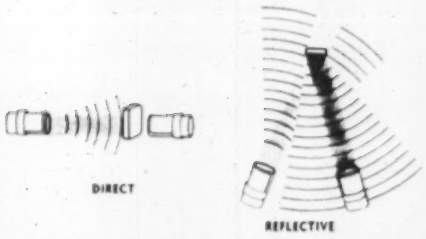
Hi-Seal offers further proof that Imperial is the company *with a habit of leadership.*

IT'S IN THE BOOK
Comprehensive data is furnished in the new Hi-Seal Catalog No. 3108 — the catalog that serves as an engineer's handbook as well. Send for your copy today.

THE IMPERIAL BRASS MFG. CO.
Dept. ICS-90, 6300 W. Howard Street
Chicago 48, Illinois

CIRCLE 36 ON READER-SERVICE CARD

Ultrasonic Sensor



Sonac is designed to sense the presence or absence of liquids or solids, ferrous or non-ferrous metals and opaque or transparent materials . . . Sonac uses ultrasonic energy for its "beam". A complete assembly consists of two acoustic sensors (matched pair) and a control-amplifier in a splash proof enclosure. The two sensors convert electrical energy to ultrasonic energy and vice versa. One sensor acts as a transmitter; the other as a receiver. The sensors can be positioned to sense an object in either a Direct path between sensors, or by a Reflective path completed by object itself. Although ultrasonic waves are transmitted from one sensor to the other at an angle of approximately 50°, an object large enough to cover the active area of the sensor will break the "beam" when using the Direct path. Smaller objects can complete a path when using the Reflective method to sense an object . . . (*From new 2-page Bulletin* 41-1, *Delavan Mfg. Co., West Des Moines, Iowa.*)

FOR THIS LITERATURE CIRCLE 194 ON READER-SERVICE CARD

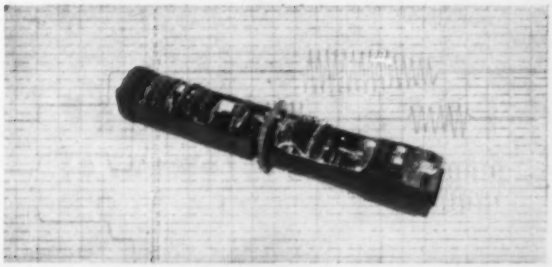
Oils, Greases, and Waxes for High Vacuum Work

	OIL A	OIL B	OIL C
Specific gravity at 20/20°C	0.872	0.873	0.880
Density g. ml at 10°C	0.875	0.977	0.881
30°C	0.862	0.867	0.870
Flash Point, Pensky Martens			
Closed	410°F	450°F	495°F
Open	425°F	455°F	510°F
Fire	460°F	510°F	575°F
Viscosity Saybolt Universal	sec	sec	sec
70°F	297	436	1250
100°F	132	182	450
130°F	74	95	202
210°F	40.5	44	60

Because of their low vapor pressures, Apiezon oils and greases are excellent lubricants in many types of high vacuum equipment; and Apiezon greases and waxes as sealing agents in high vacuum systems are unsurpassed . . . Apiezon Oils "A", "B", and "C" have vapor pressures at room temperature of 10^{-5} to 10^{-8} mm Hg, which makes them ideally suited for high vacuum diffusion pumps. These oils are produced by a special process known as "molecular distillation," which results in oils very stable to overheating without decomposition under reduced pressures and may be used in diffusion pumps in place of mercury.—(*From new* 4-*page Bulletin* 43, *James G. Biddle Co.*, 1316 *Arch St., Phila.* 7, *Pa.*)

FOR THIS LITERATURE CIRCLE 195 ON READER-SERVICE CARD

THANKS TO BRISTOL CHARTS



AND HATHAWAY RECORDER

A compact airborne recorder assembly made by Hathaway Instrument Division of Hamilton Watch Company, Denver, Colorado, is used in simulated firings to train pilots in use of the Falcon air-to-air missile.

This rugged instrument records firing data on photo oscillographic paper, preprinted with accurate amplitude and reference lines by The Bristol Company.

Bristol's chart service developed the new process which permits accurate (±0.005") printing through photo sensitive emulsions and produces preprinted photo charts for oscillograph use.

This is just one example of Bristol's ability to design a chart to meet your special instrument requirements. On specially treated, coated or laminated stock, if required. With special punchings or printing to any desired mathematical law.

Your instrument is no better than the chart it records on. So for more information on Bristol's long experience in chart engineering and accurate, economical production methods, write: The Bristol Company, 154 Bristol Road, Waterbury, Conn. 9.23

BRISTOL ...for improved production through measurement and control

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

CIRCLE 37 ON READER-SERVICE CARD

EPLAB

PYRHELIOMETER
For the Measurement of SOLAR RADIATION

Eppley Pyrheliometers are used for solar radiation measurements at ninety-eight weather stations in the continental United States, Canada, Alaska, Greenland, Iceland, Caribbean Sea, and the Pacific Ocean. Sixty-two of these stations are under the direction of the United States Weather Bureau.

The Eppley Pyrheliometer was adopted as standard equipment by the Weather Bureau after considerable experimentation. It was found to be the best instrument so far tested by the Bureau.

Used in conjunction with a suitable recorder, the Eppley Pyrheliometer will provide an accurate and reliable record of total solar and sky radiation on a horizontal surface.

Bulletin No. 2 on Request

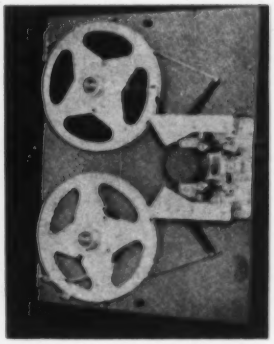
THE EPPLEY LABORATORY, INC.

Scientific Instruments

2 Sheffield Ave.
Newport, Rhode Island U. S. A.

CIRCLE 38 ON READER-SERVICE CARD

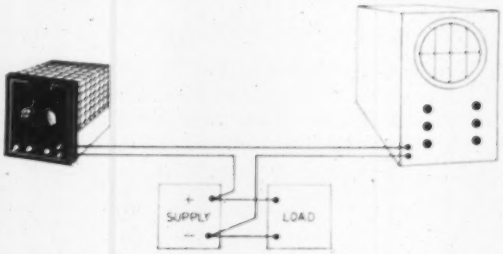
Low-Cost Transport for Low Speed Applications



The Model 3280 is a fast start-stop digital transport designed for data transfer rates of 2000 characters per second or less. Completely transistorized the Model 3280 employs the Potter long-life pinch roll assembly and is adaptable to NARTB, IBM, and RRU reels. AC motors are used in the capstan and reel drives for long dependable service. Optical end of tape sensing with a build-in amplifier providing separate indication of "load" and "physical" end of tape is available as an optional accessory. (*From new 12-page Catalog 4-59, Potter Instrument Co., Inc., Plainview, N. Y.*)

FOR THIS LITERATURE CIRCLE 196 ON READER-SERVICE CARD

D-c Voltage Reference Supply for Oscilloscopes

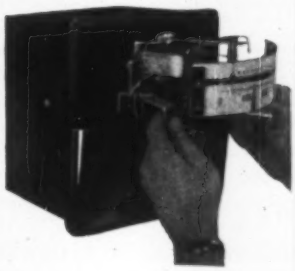


The Scope-O-Trol is a unique laboratory instrument, designed to enlarge the range of usefulness of oscilloscope observations. It provides an opposing potential which cancels out the direct current increment of a circuit being checked so that both D.C. and A.C. steady state and transient voltage changes can be observed on the scope in their true form . . . Connected to a supply source of 115 volts, 60 cycles, the Scope-O-Trol provides a regulated output range from 0 to 300 volts DC, stabilized at any desired setting. Coarse adjustment is in 75 volt steps. Fine adjustment potentiometer .25 volt/degree. Ripple: less than 1 millivolt RMS . . . (*From new 2-page Bulletin 173-BLO1, Acme Electric Corp., Cuba, N. Y.*)

FOR THIS LITERATURE CIRCLE 197 ON READER-SERVICE CARD

Ever try threading a needle
WITH ONE EYE CLOSED?

The interchangeable unit design of Wheelco Capacitrols provides the ultimate in control-instrument flexibility . . . permits on the job modifications to meet changing production demands.



TRYING to meet today's process control requirements with yesterday's instrumentation is like trying to thread a needle with one eye closed! Today's rigid processing demands the accuracy and flexibility of Wheelco Capacitrols. Why? Wheelco's interchangeable unit design (see left) for maximum flexibility permits on-the-job instrument modifications to meet changing production demands . . . plug-in chassis for fast servicing . . . a wide variation of control forms such as time-proportioning Capacitrols when system inertia compensation is necessary . . . or electric-proportioning Capacitrols for saturable core reactor control (a Wheelco first). Without qualification, Wheelco Capacitrols offer the most accurate and flexible process forms available. Ask your nearby Wheelco sales and service representative to give you complete data on all Wheelco instruments. After all, if you're using obsolete process control instrumentation, we both lose . . . right?

WRITE FOR COMPLETE ENGINEERING DATA

In addition, Wheelco Capacitrols offer exclusive "Electronic Link" no-contact control, flexibility of sensing elements, thermocouple break protection and many other advantages.

BARBER COLMAN

Wheelco Instruments Division

BARBER-COLMAN COMPANY

Dept. I, 1515 Rock Street, Rockford, Illinois, U.S.A.

BARBER-COLMAN of CANADA, Ltd., Dept. I. Toronto & Montreal

Export Agent: Ad. Auriema, Inc., N.Y.

CIRCLE 39 ON READER-SERVICE CARD

Sub-Min.

Widest selection of Pilot Lights - from DIALCO

NEON

T-2

HIGH BRIGHTNESS and REGULAR TYPES

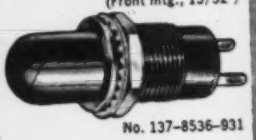
DIALCO's Sub-Miniatures use tiny T-2 Neon Glow Lamps: *NE-2J (High Brightness)* at 105-125 V., A.C.; or *NE-2D* (regular) at 105-125 V., A.C. or D.C.

NEW Series mounts from *FRONT* of panel in 15/32" clearance hole (supplements 17/32" Series). Also—units for mounting from *BACK* of panel in 15/32" clearance hole. Unique lenses in 5 colors; give all-angle visibility. Units are fully insulated; meet applicable Mil. Specs.

Ask for Brochures L-159B and L-162.

(Illust. approx. actual size)

(Front mtg., 15/32")



No. 137-8536-931

(Front mtg., 17/32")

No. 145-5036-991

(Back mtg., 15/32")

No. 138-3836-1431-99

DIALCO

INCANDESCENT

T-1¾

2-TERMINAL and 1-TERMINAL TYPES

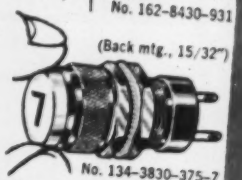
Designed for use with T-1¾ midget flanged incandescent lamps—1.3 V. to 28 V... *NEW* Series mounts from *FRONT* of panel in 15/32" clearance hole—(supplements 17/32" Series). Also—units for mounting from *BACK* of panel in 15/32" clearance hole. Unique lenses in 7 colors. Units are fully insulated; meet applicable Mil. Specs.

Ask for Brochures L-156C thru 159B, and L-162.

(Front mtg., 15/32")

No. 162-8430-931

(Back mtg., 15/32")



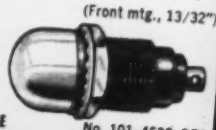
No. 134-3830-375-7

Spring-mounted Lens-with-Message is *rotatable*.

1-Terminal Pilot Lights

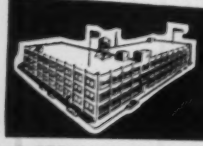
For use on *grounded circuits*. Mount in 13/32" or 15/32" clearance hole. Binding screw or soldering terminal.

(Front mtg., 13/32")



No. 101-4630-971

SAMPLES ON REQUEST—AT ONCE—NO CHARGE



Foremost Manufacturer of Pilot Lights

DIALIGHT CORPORATION

42 STEWART AVE., BROOKLYN 37, N. Y. • HYacinth 7-7600

CIRCLE 40 ON READER-SERVICE CARD

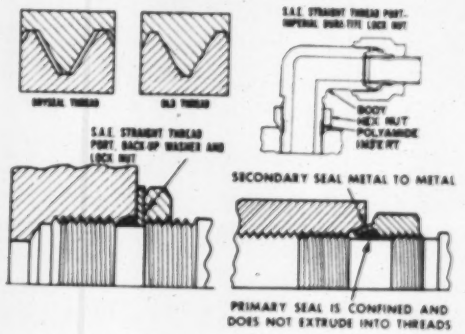
IGS BRIEFS

Digital Differential Analyzer

The SPEC DDA is a stored program digital differential analyzer specifically designed to solve mathematical problems involving differential equations. Problem solutions are obtained by programming the appropriate interconnections between digital integrators in accordance with the specific nature of the problem. . . . The SPEC DDA contains twenty such integrators. Integration capability with respect to any independent variable, including time, permits its utilization for the solution of a wide variety of linear and non-linear differential equations. Programming restrictions have been kept to a minimum to insure ease of programming . . . (*From new* 14-*page Catalog S-1, Computer Control Co., Inc., 2251 Barry Ave., Los Angeles 64, Calif.*)

FOR THIS LITERATURE CIRCLE 198 ON READER-SERVICE CARD

Tube Fittings



Standard pipe threads are the common connection between tube fittings, valves and other components. Hi-Seal is furnished with long Dryseal Pipe Threads. Dryseal threads have a flat on the root wider than the flat on the crest. Because of this, contact between root and crest is assured before the flanks of threads engage. Also, spiral clearance—often a problem with the former American Standard—is eliminated. . . .

For connecting into ports of hydraulic valves and other parts, the O-Ring seal offers these advantages: It eliminates the possibility of broken fittings, deformed housings, and cracking of ports which result from over-torquing with pipe threads. And O-Ring seal also lets you position elbows and tees so that tube ends will always be in proper alignment. . . . Dura-Tite features a lock nut with a tubular portion at its base. A split ring, made of a special polyamide formulation, is confined between the tubular section and the fitting groove. Dura-Tite uses a primary and secondary seal for effectiveness . . . (*From new* 48-*page Catalog* 3108, *Imperial Brass Mfg. Co., 6300 W. Howard St., Chicago 48, Ill.*)

FOR THIS LITERATURE CIRCLE 199 ON READER-SERVICE CARD

NEW BAILEY
Multi-Pointer Gage

...has twice as many indicators
...no taller than a telephone!

Now the popular versatile Bailey Multi-Pointer Gage has been reduced in size to conserve control panel space—without loss of easy *readability*.

Each new Multi-Pointer Gage Unit offers you these three choices to—

1. Measure and indicate draft, pressure, differential pressure and level.
2. Transmit above variables either pneumatically or electrically to remote indicators, recorders and/or controllers.
3. Receive and indicate any measured variables which may be transmitted pneumatically by standard SAMA ranges of 3-15 psig. or 3-27 psig.

FEATURES

Compact Size—Two large, easily-read 7" scales in space only 4 inches wide.

Wide Range Selection—Standard ranges from 0-0.5 in. H_2O to 0-5000 psig available.

Choice of Standard Colors—Satin Black, Slate Gray, Moss Green, or Terra Tan may be selected as an exterior color at no additional cost.

Colored Scales—Scales available in white, red, green, blue, yellow, or orange.

Fluorescent Illumination—All gages have slideout unit containing bulb and starter for ease of maintenance.

Readily Accessible Adjustments—Zero adjustment made from front of gage. Other adjustments made from rear of gage.

Two-point Positive Mounting—Gage unit mounted with two clips . . . no holes to drill or studs to weld.

Unlimited Indications—Any number of basic two-indicator units may be placed side-by-side to provide indications of related factors. Each two-indicator unit is separatelymounted.

For additional information, call your local Bailey District Office, or write us direct. G47-1

Instruments and controls for power and process

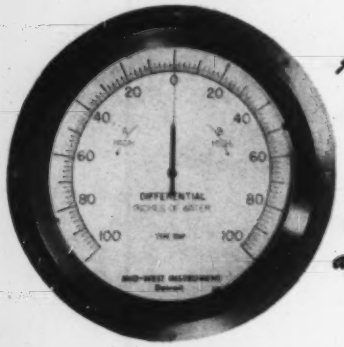
BAILEY METER COMPANY

1041 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

CIRCLE 41 ON READER-SERVICE CARD

DIFFERENTIAL GAUGES



A rugged, dependable instrument to fit your applications

MID-WEST DIFFERENTIAL INSTRUMENTS OFFER:

☆ 4000 PSI WORKING PRESSURE
☆ FULL OVERRANGE PROTECTION
☆ 100 INCHES OF WATER TO 400 PSID
☆ STANDARD & PRECISION MODELS

SPECIAL DESIGNS MADE TO ORDER

MID-WEST INSTRUMENT DIV.
ASTRA ASSOCIATES INC., 1021 E. STATE FAIR
DETROIT 3, MICHIGAN

CIRCLE 42 ON READER-SERVICE CARD

NEW NEW NEW NEW NEW NEW NEW NEW NEW

when it MELTS you know the *temperature!*

NEW *Markal* **THERMOMELT TEMPERATURE INDICATORS**

With Handy Adjustable Holder

The easy modern way to determine exact working temperatures!

Just mark or stroke the surface with THERMOMELT . . . when it reaches the desired temperature, the mark liquefies. There's no guesswork, no wasted time or material . . . THERMOMELT is the quick, precise way to determine heating temperatures. Accurate to within ±1%.

A Stik For Every Temperature from 113° F. to 2000° F.

SEND TODAY for free THERMOMELT literature and pellet sample (indicate temperature desired).

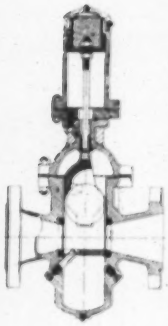
ALSO AVAILABLE IN LIQUIDS AND PELLETS for inaccessible or hard-to-measure applications. Wide range of temperatures.

Made by the Manufacturers of Markal Paintstik Markers and Protective Coatings.

MARKAL CO. 3080 West Carroll Avenue • Chicago 12, Illinois

CIRCLE 43 ON READER-SERVICE CARD

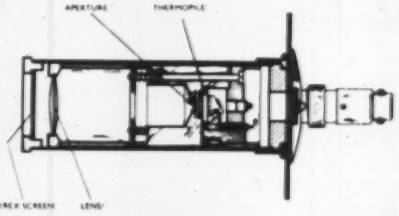
Venturi-Ball Valves



The valve is based on a unique Venturi-ball design which provides the most efficient throttling control ever devised capable of handling a broad range of applications. . . . The exceptionally high flow capacity of the P-K Paul Valve is perhaps its most outstanding single feature. . . . The flow characteristic (relationship between lift of the stem and flow through the valve) of the P-K Paul Valve is essentially linear over the complete stroke but falls between the equal percentage and linear curve. . . . The P-K Paul Integral Cylinder Valve is a self-contained, self-regulating valve that requires no outside power source for operation. It is supplied for all liquid gas services for applications and installations where it is difficult or impossible to supply an outside power source. . . . The valve will maintain any predetermined downstream pressure or flow requirement without an outside controller . . . (*From new 16-page Bulletin GV-101, General Kinetics Corp., 197 South Van Brunt St., Englewood, N. J.*)

FOR THIS LITERATURE CIRCLE 200 ON READER-SERVICE CARD

Land Radiation Pyrometers



The West-Land Radiation Pyrometer is not just a "radiation tube" but a precision instrument of high sensitivity and rugged construction, calibrated to a standard of precision as high as the best base-metal thermocouples. Every pyrometer of the same type has the same calibration so that they may be interchanged.

West-Land pyrometers are temperature compensated to enable them to measure true temperature whether they are hot or cold. The reading remains constant if the size of the hot object is increased. Distance to the hot object can be varied as long as the target size is larger than that required for a particular distance. (*From new Bulletin RAD, West Instrument Corp., 4363 W. Montrose Ave., Chicago 41, Ill.*)

FOR THIS LITERATURE CIRCLE 201 ON READER-SERVICE CARD

sharp

AMERICAN BI-METAL THERMOMETERS make accurate temperature readings sharp and sure at all check points

American Dial Thermometers are also available in mercury, vapor pressure, and gas actuation . . . on-the-spot and distant reading types . . . in sizes, ranges and stem lengths to meet your most exacting requirements.

sensitive

Any way you look at an American Bi-Metal Thermometer, you see exact working temperatures.

The two-level "Maxivision®" dial eliminates parallax effects. Numerals are on the lower level. Graduations are on the outer raised ring dial which presents a sheared edge to the tip of the pointer and in the same plane. To make readability even more accurate, the glass and graduated dial are closely spaced.

American Bi-Metal Thermometers are made of weather-proof stainless steel. All joints are welded to solid unity, then polished smooth so corrosion won't build up and destroy the thermometer's usefulness. And, you don't have to discard this thermometer even if the glass is ever broken. The bayonet lock bezel makes replacement easy.

Learn about the high sustained accuracy and long service life built into American Bi-Metal Thermometers. Phone your nearby industrial supply distributor for help in selecting the right type for each temperature check point in your plant. Or write for Catalog 100A.

MAXWELL MM&M MANNING & MOORE, INC. TRADE MARK

AMERICAN INDUSTRIAL THERMOMETERS

A product of

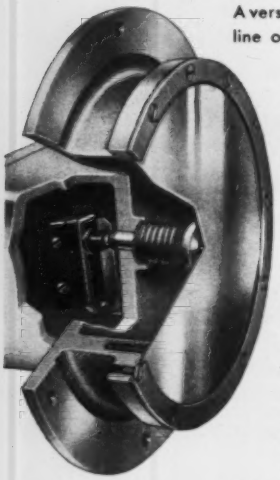
MANNING, MAXWELL & MOORE, INC.

Gauge and Instrument Division • Stratford, Connecticut
In Canada: Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario

CIRCLE 44 ON READER-SERVICE CARD

NEW
AUTO-BIN-DICATOR*

AUTOMATIC BIN LEVEL INDICATOR



A versatile addition to the Bin-Dicator line of bulk material level controls.

NEW corrosion-resistant construction

NEW stainless steel diaphragm

NEW super-sensitive operation

Explosion-proof and general purpose models listed by Underwriters' Laboratories, Inc.

Prevents overflowing of bins, clogging of conveyors, choking of elevators, damage to machinery; cuts operating costs. Provides simple, reliable, positive control at low cost.

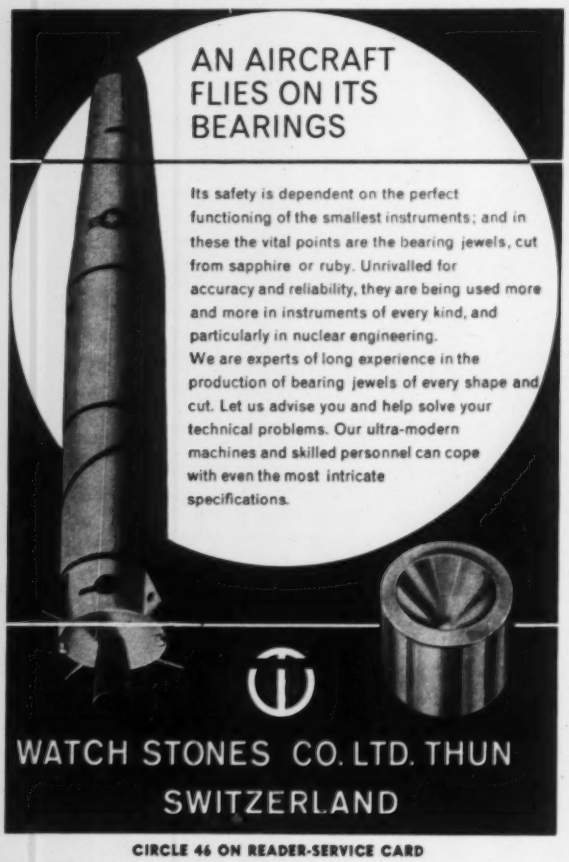
WRITE for Bulletin AB-19 or call VAlley 2-6952

THE BIN-DICATOR CO.
13946-B4 Kercheval • Detroit 15, Mich.

*TM PATENT PENDING

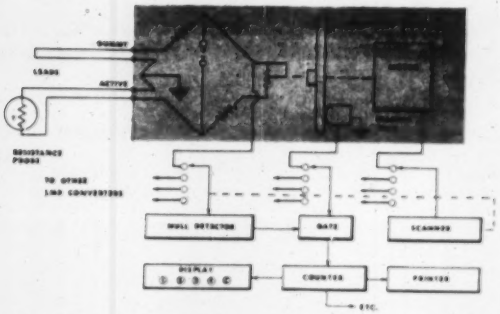
WE SELL DIRECT • PHONE ORDERS COLLECT

CIRCLE 45 ON READER-SERVICE CARD


AN AIRCRAFT FLIES ON ITS BEARINGS
Its safety is dependent on the perfect functioning of the smallest instruments; and in these the vital points are the bearing jewels, cut from sapphire or ruby. Unrivalled for accuracy and reliability, they are being used more and more in instruments of every kind, and particularly in nuclear engineering.
We are experts of long experience in the production of bearing jewels of every shape and cut. Let us advise you and help solve your technical problems. Our ultra-modern machines and skilled personnel can cope with even the most intricate specifications.
WATCH STONES CO. LTD. THUN
SWITZERLAND

CIRCLE 46 ON READER-SERVICE CARD

Multichannel Digitizer

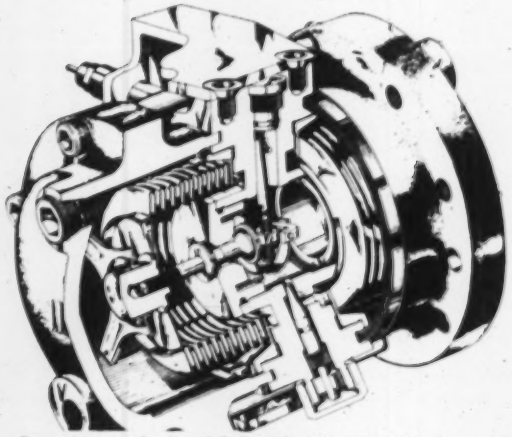


The LMD will provide a linear digital response to a non-linear analog input by using a scanning input technique and a unique analog to digital converter. . . .

A magnetic disc and a potentiometer form the heart of the LMD converter. The Potentiometer, as part of the input circuit, scans the full range of input once each revolution of the motor drive. On the same shaft, a magnetic disc having a prerecorded train of magnetic bits is rotated and scanned by a magnetic reading head. At the start of each scan, the counter begins to totalize the incoming magnetic signal until the null detector senses that the input circuit is passing precisely through the balance point. The null detector closes the gate at the instant of balance preventing more bits from being counted, although the shaft finishes its rotation, and stops. The count is then displayed and printed for a permanent record . . . (*From new 2-page Bulletin 46029, Rosemount Engineering Co., 4900 West 78th St., Minneapolis 24, Minn.*)

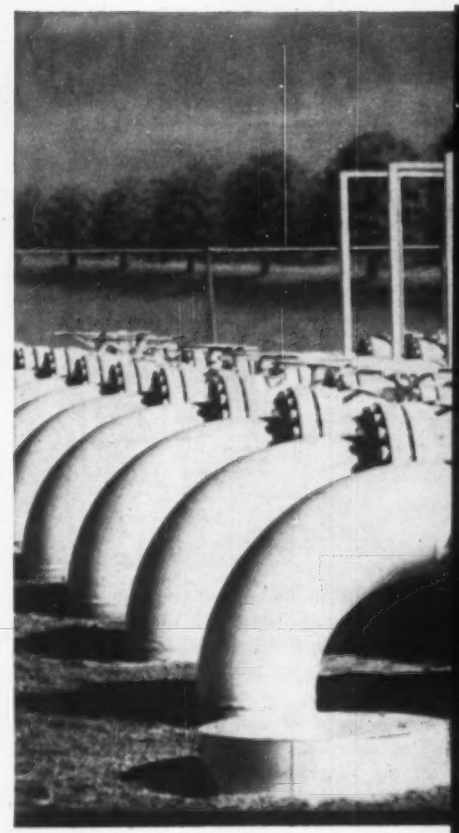
FOR THIS LITERATURE CIRCLE 202 ON READER-SERVICE CARD

D-P Flow Meters



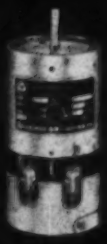
Operation of the I.I.C. Model 1700 Differential Pressure Unit is based on the interaction of two opposed bellows attached to a machined center plate. All space enclosed by the two bellows is completely evacuated and fluid filled. The low-pressure bellows shaft is connected by linkage to transmit bellows motion to the I.I.C. Non Freezing Bearing Shaft.
(*From new 12-page Bulletin 56-B-3, Industrial Instrument Corp., P. O. Drawer 777, Austin, Tex.*)

FOR THIS LITERATURE CIRCLE 203 ON READER-SERVICE CARD



ORIFICE METERS

American-Westcott Dri-flo and mercury manometers in recording, indicating and integrating models—to 5000 psi working pressure.



GASCLOK

Gas or air-operated instrument power drive and timing unit for remote installations.

CANNON PENS

Controlled flow capillary meter pens record up to a full year without refilling—eliminate chart smearing and blurring.

CONTROLLERS

Series A-88 Controllers, Transmitters & Receivers for control of continuous process variables. Telemetering Systems designed to meet your requirements.

RELY ON AMERICAN® INSTRUMENTS FOR YOUR TOUGHEST JOBS

American's complete line of equipment sets the highest standards for accuracy and dependability. Ask your American representative about their applications and advantages for your measurement and control problems.

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METER COMPANY
INCORPORATED ESTABLISHED 1836

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SUPPLIERS TO THE GAS INDUSTRY for Ironcase, Tinned Steelcase, Aluminumcase and Welded Steelcase Meters • American-Westcott Orifice Meters • Instruments • Reliance Regulators • Apparatus • Valves

CIRCLE 47 ON READER-SERVICE CARD

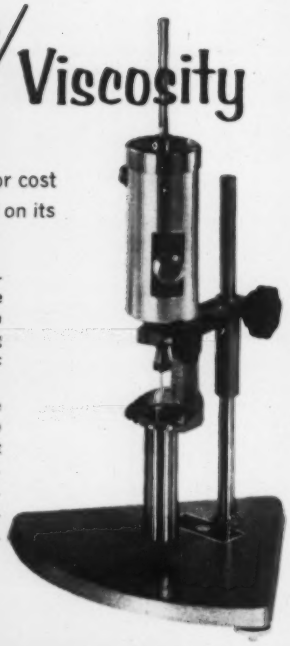
Rheology / Viscosity

Does the quality or cost of your product depend on its flow characteristics?

► A complete line of Epprecht Viscometers provide viscosity measurements in the laboratory or during processing with automatic control of viscosity.

► Measurements can be made at pressures up to 700 psi or in a vacuum at temperatures to 300° C.

For detailed technical information on Epprecht Viscometers write to Dept. DV-3.



J. W. FECKER DIVISION
AMERICAN OPTICAL COMPANY

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CIRCLE 48 ON READER-SERVICE CARD

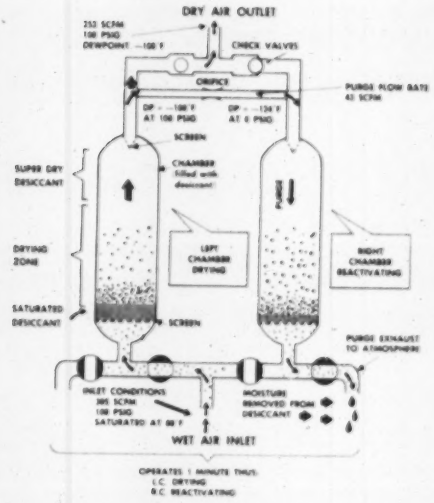
TYLOK
TUBE COUPLINGS

"TYLOK" 4 Seal Coupling design is the most complete answer to difficult tube problems on the market today.
"TYLOK" couplings will hold against all pressures, temperatures, vibrations and surge beyond the rupture yield point of any tubing, regardless of material or wall thickness . . . including all brands of plastic tubing.
There is a "TYLOK" tube coupling to meet your needs, write, wire or phone for further information and catalog.

C. B. CRAWFORD COMPANY
16606 Waterloo Road, Cleveland 10, Ohio

CIRCLE 49 ON READER-SERVICE CARD

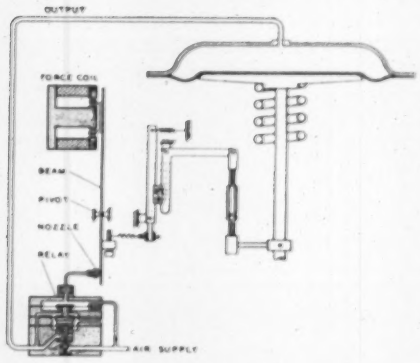
Air Dryers



Heat-Les Dryers utilize the natural tendency of desiccants to come into equilibrium with their surroundings. During the drying cycle, the desiccant absorbs moisture from the incoming gas stream. During the reactivation cycle, a small portion of the super-dry gas is passed over the desiccant at atmospheric pressure, creating an environment in which the desiccant must give up the previously absorbed moisture to reach equilibrium . . . (*From new 6-page Bulletin HA-308, Trinity Equipment Corp., Cortland, N. Y.*)

FOR MORE INFORMATION CIRCE 204 ON READER-SERVICE CARD

Valve Positioner



The positioner is a force-balance electropneumatic device which provides an accurate means of obtaining a valve stem poistion directly proportional to a dc input signal. In addition, the positioner provides a convenient means of split-ranging controller output signal for sequential operation of two control valves by a single controller . . . (*From new 8-page Instruction Sheet 2027, Mason-Neilan, Div., of Worthington Corp., Norwood, Mass.*)

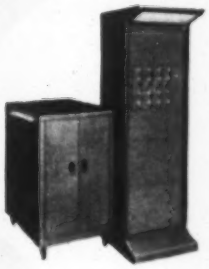
FOR MORE INFORMATION CIRCLE 179 ON READER-SERVICE CARD

The Offner Type R All Transistor Dynograph

provides greatest versatility

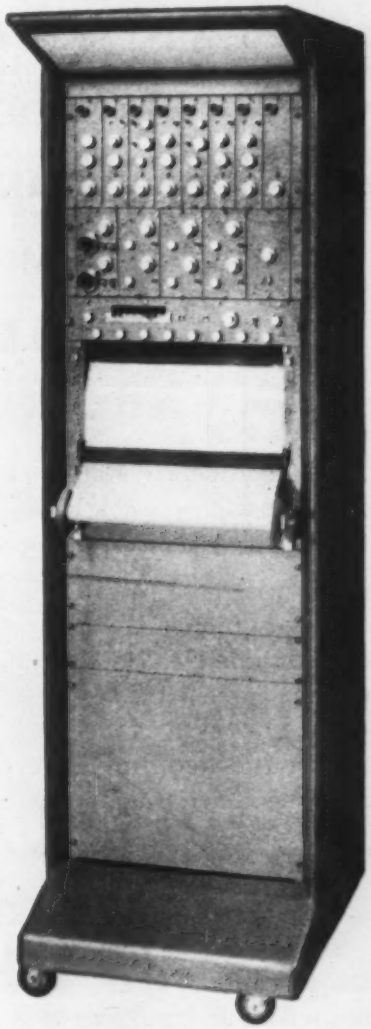
RP TWO CHANNEL
Compact, economical, convenient where only one or two channels are desired.

BMM/B CONSOLE
Features horizontal paper travel. Available as Type R or RC.



R SIXTEEN CHANNEL
Assemblies with 16 channels. 24 inch paper permits up to 24 channels on one inch centers.

RC DESK-TYPE CONSOLE
Medium gain assembly for computer write-out, telemetering, applications with input signal above 10 millivolts.



Write on your company letterhead for Bulletin 891, a 20 page, 2 color brochure giving you complete specifications, application data, etc.

VERSATILITY of assemblies—select the mounting best suited for your use.

VERSATILITY of application—one set of amplifiers covers all uses, microvolt to volts dc or ac, strain gages, reluctance gages, etc.

VERSATILITY of writing media—use ink, heat, electric interchangeably on one assembly—select the one most suited for the application.

The Offner Type R Dynograph Assembly is unmatched for sensitivity, accuracy, versatility—we invite you to compare it with any other high speed direct writing oscillograph.

OFFNER ELECTRONICS, INC.
3910 River Road, Schiller Park

SCHILLER CO.
...oad, Las Vegas, Nevada
...ing address P. O. Box 4426

CIRCLE 53 ON READER-SERVICE CARD

CIRCLE

WHERE DO YOU STAND ON COMPUTER CONTROL— LEADING OR LAGGING?

Far-sighted leaders in industry are realizing the benefits made possible by applying computer control systems to their processes.

Working with these leaders, General Electric has already pioneered the application of twenty on-line GE-312 computer systems now being implemented in these basic areas —STEEL, ELECTRIC UTILITIES, CHEMICAL, CEMENT, and PRODUCTION CONTROL for various manufacturing applications.

The GE-312 Computer Control System embodies adaptability and flexibility to meet many types of applications in varying size plants. For example, compare its expansible memory—capacity up to 52,000 words. Compare its flexible input/output—capable of scanning up to 1500 instrument inputs. These are maximum capabilities, expansible from a minimum system. You buy a system tailored to your exact requirements.

Add to this versatile equipment the computer systems engineering ability demonstrated by General Electric in implementing these twenty GE-312 system applications.

Add also the long history of General Electric overall systems know-how—its broad background in the equipment, processes and materials to which you apply computer control.

Tomorrow's profits will come from today's combination of vision, equipment, and know-how. *Where do you stand?*

There are General Electric Sales and Application engineers in over one hundred offices throughout the nation to serve you. *Phone* the nearest General Electric Apparatus Sales Office, or *wire* General Electric Computer Department, 13439 North Black Canyon Highway, Phoenix, Arizona.

PROCESS CONTROL
AUTOMATED BY GENERAL ELECTRIC

Progress Is Our Most Important Product

GENERAL ELECTRIC

General Electric—a pioneer in computer systems for all phases of business, industrial, scientific, engineering, and financial endeavor.

CIRCLE 51 ON READER-SERVICE CARD

BRIEFS

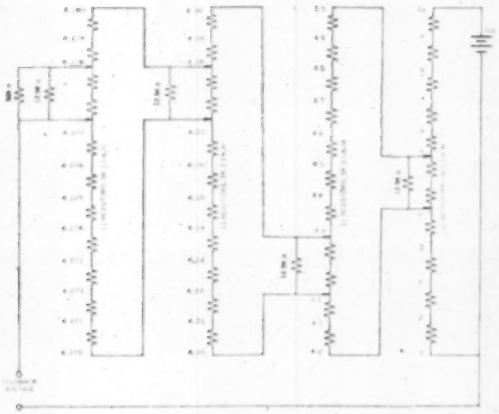
High-Speed Graph Plotter

Accurate, high-speed graphic output—useful in a wide range of scientific and business applications—is now available for both the Bendix G-15 computer and for its digital differential analyzer accessory.

Under program control, the full transistorized graph plotter operates at a maximum speed of 200 increments per second and with accuracy of ±.005 inch. If high speed point-to-point (discontinuous) plotting is desired, the user may specify a program-controlled retractable pen. This optional features also permits plotting to begin at any point on the page, and eliminates retrace line.—(*From new 2-page Bulletin AN-0460, The Bendix Corp., Computer Div., 5630 Arbor Vitae St., Los Angeles 45, Calif.*)

FOR THIS LITERATURE CIRCLE 205 ON READER-SERVICE CARD

Digital Voltmeters



Series 30 instruments for measuring voltage and voltage ratio—the four-digit and five-digit V35—are designed for applications demanding utmost reliability. . . .

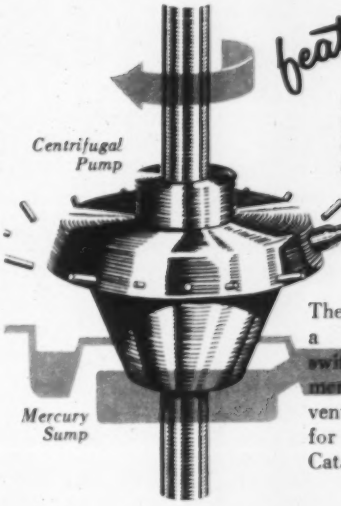
Major advantages result from the use of the new Iso-Ohmic bridge in Series 30 instruments. Originated by NLS, the Iso-Ohmic bridge is a Kelvin-Varley voltage divider modified so that the value of each decade resistor is the same. As illustrated in the diagram, the secret of this new concept is the addition of a shunt resistor 2½ times the magnitude of the individual decade resistors. This meets the requirement that the combined impedance of the two shunted resistors be equal to that of a single unshunted resistor, with all decade resistors having the same value. Not only does the Iso-Ohmic bridge make all decade switches interchangeable, but it also assures long-term accuracy because all critical resistors are wound with the same number of turns of the same resistance wire . . . (*From new 20-page Bulletin 8159, Non-Linear Systems, Inc., Del Mar (San Diego), Calif.*)

FOR THIS LITERATURE CIRCLE 206 ON READER-SERVICE CARD

DELTASWITCH

PATENTED

A HIGH SPEED MERCURY COMMUTATING SWITCH



featuring

NO "CONTACT BOUNCE"
LOW NOISE LEVEL
HIGH SAMPLING RATE
ONLY MAINTENANCE-CLEANING

The DELTASWITCH is a unique commutating switch in which a jet of mercury replaces the conventional wiper arm. Send for more details. Ask for Catalog ATL-19.

ADVANCED Technology LABORATORIES
A DIVISION OF AMERICAN-Standard

DEPT. AEI 369 Whisman Road, Mountain View, California

CIRCLE 52 ON READER-SERVICE CARD

HELLER

electronic, variable-speed
AC CONTROLLER
and matching
DC MOTOR

Complete, F.O.B., Las Vegas, Nevada

$87

2T60 ELECTRONIC CONTROLLER with matching 1/50 H. P. DC MOTOR

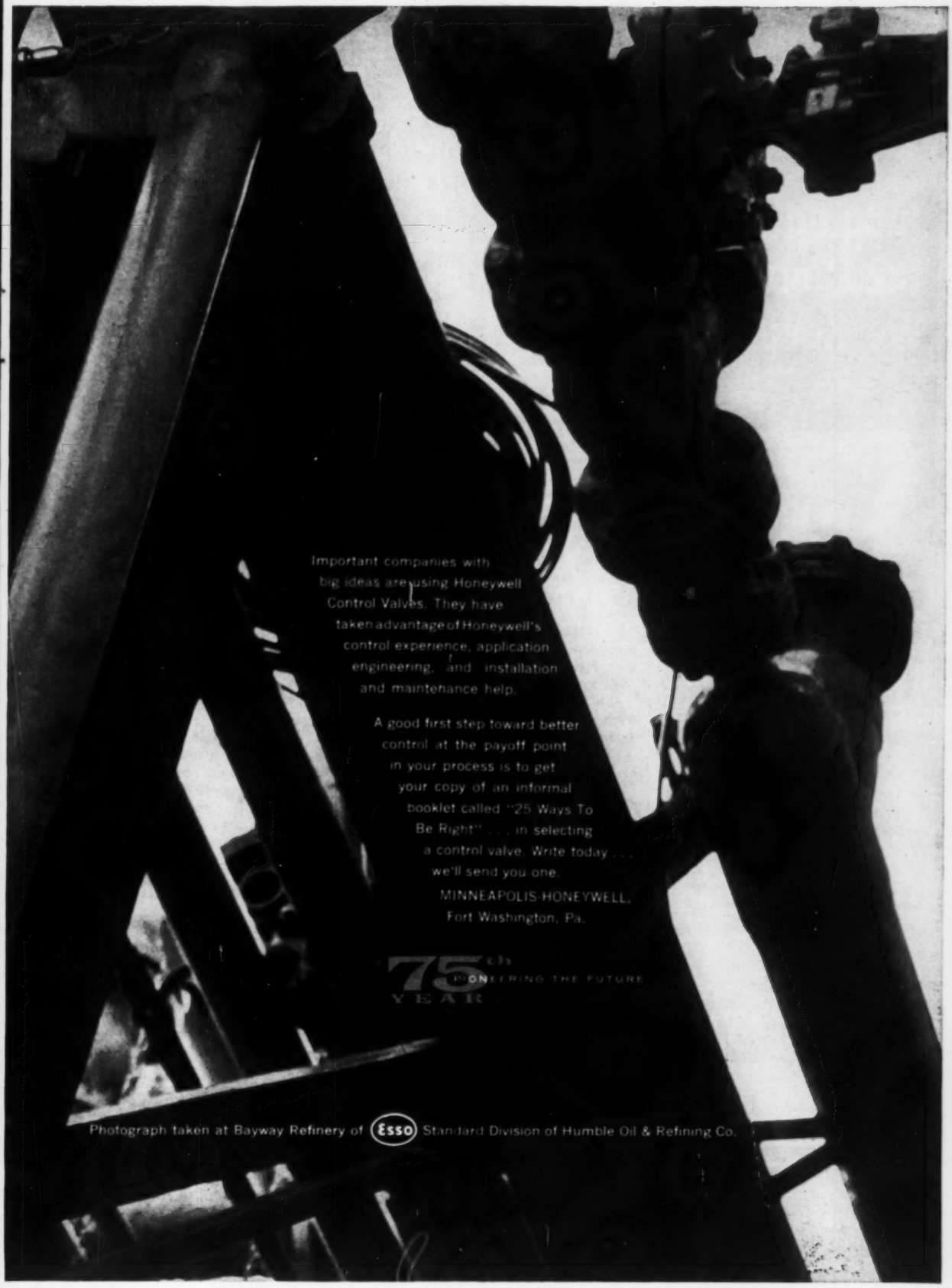
SPECIFICATIONS

• Thyraton tube operated controller gives stepless operation • Input: 110-120 V., 60 cy. single phase • Output: 0-120 V., 200 ma. DC to armature • 1/50 H.P. ball bearing, right angle, gear head, shunt wound, DC motor • Reversible • Armature speed 0 to 4000 R.P.M. • Armature shaft is extended • Motors in gear ratios: 6, 18, 30, 36, 60, 100, 300, 540, and 1120:1 in stock.

GERALD K. HELLER CO.
1819 Industrial Road, Las Vegas, Nevada
Mailing address P. O. Box 4426

CIRCLE 53 ON READER-SERVICE CARD

CIRCLE 54 ON READER-SERVICE CARD


Important companies with big ideas are using Honeywell Control Valves. They have taken advantage of Honeywell's control experience, application engineering, and installation and maintenance help.
A good first step toward better control at the payoff point in your process is to get your copy of an informal booklet called "25 Ways To Be Right" . . . in selecting a control valve. Write today . . . we'll send you one.
MINNEAPOLIS-HONEYWELL
Fort Washington, Pa.
75th YEAR
PIONEERING THE FUTURE
Photograph taken at Bayway Refinery of Esso Standard Division of Humble Oil & Refining Co.

CIRCLE 54 ON READER-SERVICE CARD

Carrier Linde PERMUTIT DU PONT

Judging by the Company We Keep...

Electro-Mech

. . . "the Company We Keep" have acquired confidence in the dependability that comes with each Control System bearing "The Nameplate of Quality:"

Our customers know we are keenly aware of the responsibilities they entrust to us each time we're contracted to manufacture a highly specialized Control System.

Among these responsibilities are:

- Accurate, detailed engineering drawings;
- Coordinated purchasing and expediting of component equipment;
- Completely competent manufacturing procedures;
- Thorough inspection prior to shipment;
- Delivery schedules dependably met;
- Thorough communication over entire progress of job.

These are a few of the things that have gained for us such a highly respected group of industrial customers —We invite you to join "the Company We Keep" with our quotation on *your* next Control System requirement.

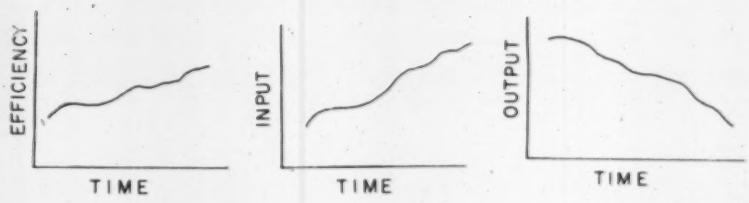
Electro-Mech Corp., Norwood, N. J.

Electro-Mech

CIRCLE 55 ON READER-SERVICE CARD

IGS PANHANDLE PETE

WESCO! Announces Special-Logic Control Computer—EFFCON



WESCO! announces that symbolic logic has been combined with a process control computer for the first time to solve the number-1 problem in the process field, automatically and instantaneously—maintaining optimum process efficiency. The key to this dramatic breakthrough in computer control was found in a combination of symbolic-logic and adaptable control techniques. The former technique uses logic to arrive at the desired conclusion (ever-increasing efficiency) and the latter technique permits the experience of time t_1 to be applied to the results of a latter time t_2—a "learning" situation.

The new circuit is based on a five-year analysis of hundreds of men who reported methods whereby efficiency was increased despite adverse circumstances—low quality of raw materials, high cost of power, etc.

The logic used by these engineers to arrive at their ever-increasing efficiency is now incorporated in the new WESCO! EFFCON—efficiency controller. It was found to be based on a factor known as the EFF-factor, which adapts itself automatically to the process. Once the computer is in control, the computer reports gains in efficiency, completely independent of the inputs and outputs of the process. The charts show a typical run on a typical process, with the EFF factor set at 0.2 "betters per minute"—a new unit telling how much better the process is now than it was a minute ago. Circuits can be adjusted to obtain from 0.1 to 99.99 bpm. The higher ranges are recommended only in large firms with more remote managements.

The special-logic element is available only as an accessory with the WESCO! process control computer. It has been patented, and 47 lawsuits are now in preparation against computer manufacturers here and abroad.

WESCO! Answers the Education Challenge

The President's Committee on Education Beyond High School in November 1956, reported: " . . . of our nation's most talented high-school graduates who do not go on to college, approximately 100,000 each year are deterred chiefly for financial reasons; perhaps another 100,000 for lack of motivation."

WESCO! answers this threat to America's future and security by announcing the *Panhandle Pete Engineering Scholarship Foundation*, dedicated to assisting the development of US Technical Manpower. Five Deans of leading American Universities plus five Chairmen of the Boards of leading American Corporations will be made into a Committee of Directors, who will screen applicants. Any high-school student can apply. The Committee also will include leading physicists of the country. Tests for twenty types of aptitudes will be given, and awards will be made on the basis of scholastic achievement, aptitude and need.

Original WESCO! donation to fund is $10,000, as follows:

Meeting Expenses for Committee of Directors	$2,000
Press meeting to announce award	2,000
Fee to Public Relations Firm	3,000
Press kits with photographs	2,200
Scholarship	800

One full scholarship a year will be awarded.

Panhandle Pete

LOG FOR LESS

...$575 to $1100 less with the new NLS 484 digital voltmeter

Here is the only 4-digit voltmeter to provide printer connection and automatic print control for only $2150 . . . the only digital voltmeter at this price to provide heavy duty *plug-in stepping switches*, snap-out readout, and simple single-package design. With plug-in NLS accessories it forms a host of automatic data logging systems. Performance? The 484 retains the basic design and quality construction of the NLS 481, the world's most popular 4-digit voltmeter. Contact NLS for complete information on the 484 if you require ±0.01% accuracy and printout at low cost.

BRIEF SPECIFICATIONS: Accuracy ±0.01% of full scale on each range . . . ranges: ±9.999/99.99/999.9 volts DC, ±99.99/999.9 millivolts DC using NLS 140 Preamplifier, 9.999/99.99/999.9 volts AC using NLS 125B AC/DC Converter . . . input impedance: 10 megohms at balance, 1000 megohms on lowest range by modification . . . automatic range and polarity selection . . . balancing time: 1 sec., average . . . internal standard cell for verification of calibration . . . simple conversion to ratiometer.

Originator of the Digital Voltmeter

non-linear systems, inc. DEL MAR (SAN DIEGO), CALIFORNIA

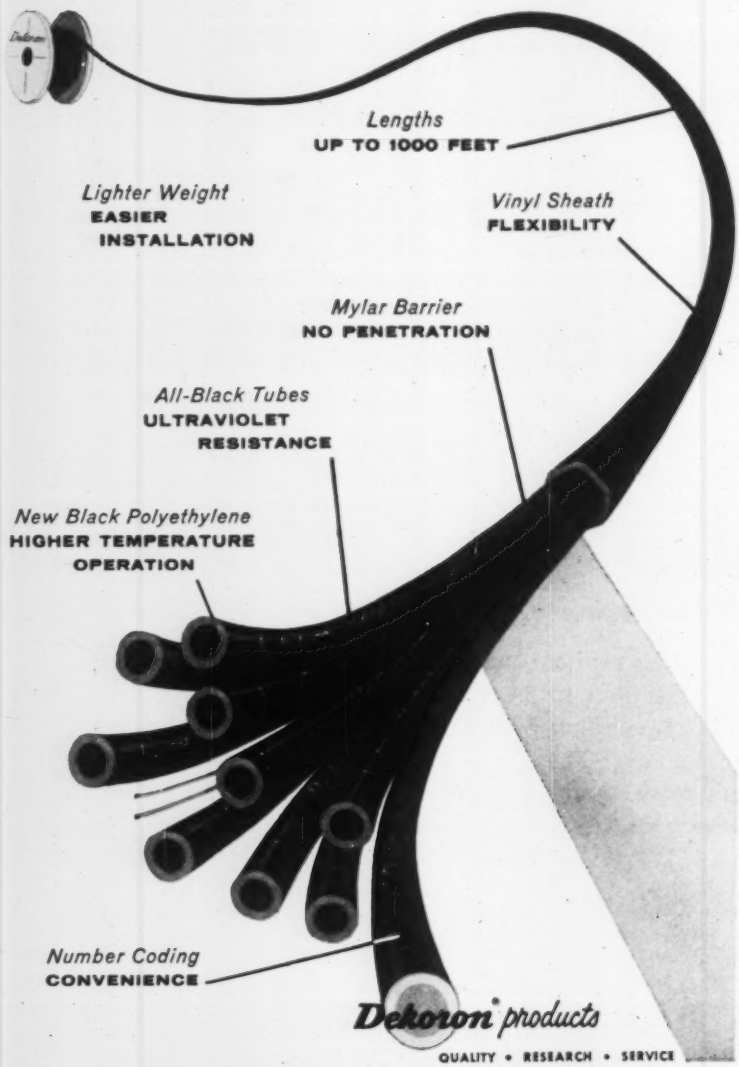
CIRCLE 56 ON READER-SERVICE CARD

WIDER CHOICE
DEKORON®
NEW POLY-COR

Dekoron products are first in the field for wide selection . . . quality . . . service . . . new product development. And the New Poly-Cor is the latest development to make instrument tubing news.

For here is a superb instrument line harness of exceptional quality with features never before available. Check them carefully. New grade of all-black polyethylene for operation at higher temperatures . . . number coding of tubes for easier hook-up . . . Mylar® vapor barrier . . . lighter weight. All these features are now standard in New Poly-Cor — and at no increase in price.

Request a Dekoron sample today and get full specification data from your local representative. Dekoron products represent years of experience in the instrument field . . . are application-engineered by the company with the greatest application experience. A-2751A



SAMUEL MOORE & COMPANY
DEKORON PRODUCTS DIVISION • **MANTUA, OHIO**
CIRCLE 57 ON READER-SERVICE CARD

IGS BOOKS

For more information on these books, or for publisher's book list circle number on reader-service card.

Algebras and their Arithmetics by Leonard E. Dickson [c1960] Dover Publications, Inc., N. Y., N. Y. 241 + xii pp, paperbound, $1.35. Foundation and background necessary for any undergraduate or graduate student studying abstract algebra.

CIRCLE 207 ON READER-SERVICE CARD

Basics of Gyroscopes, Volumes 1 & 2, by Carl Machover [c1960] John F. Rider Publisher, Inc., 116 W. 14th St., N. Y., N. Y. Vol. 1 is 112 pp; Vol. 2 is 120 pp, paperbound $6.60 set, clothbound $7.75. Present for non-specialist a basic explanation of principles underlying science of gyroscopes. Some math.

CIRCLE 208 ON READER-SERVICE CARD

Nuclear Reactor Physics by S. E. Liverhant [c1960] John Wiley & Sons, 440 4th Ave., N. Y. 16, N. Y. 447 + xiv pp, clothbound. Deal with physical principles of neutron chain reactors in a systematic and logical order.

CIRCLE 209 ON READER-SERVICE CARD

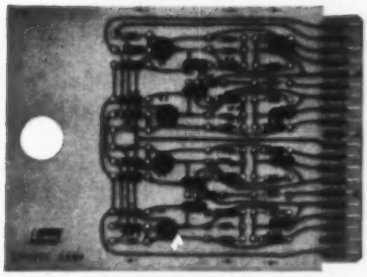
Electrical Noise — Fundamentals and Physical Mechanism by D. A. Bell [c1960] D. Van Nostrand Co., Inc., 120 Alexander St., Princetown, N. J. 342 + x pp. Clothbound. A unified reference and source book on electrical noise concerned primarily with mechanism of noise in physical devices.

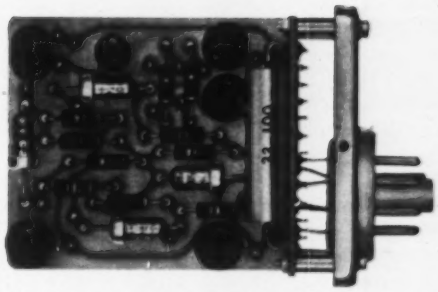
CIRCLE 210 ON READER-SERVICE CARD

Hardness—Theory and Practice by Louis Small [c1960] Louis Small, Service Diamond Tool Co., Ferndale, Mich. 549 + xxv pp. Clothbound. A complete summary of the state of the art and a valuable reference. Shows construction, specifications, operation, evaluation of results of all types or hardness tests and testing equipment.

CIRCLE 211 ON READER-SERVICE CARD

FOR SYSTEM DESIGN





DIGITAL TECHNIQUES

ANALOG TECHNIQUES

Combined by Link to give you Dialog* Systems Utilizing Available Components and Building Blocks

Link's proved analog and digital capabilities are available to help you with your system design requirements. By offering a wide variety of analog and digital modules, Link provides the building blocks that facilitate system design and reduce costs.

Listed below are Dialog system components for control, computation and simulation.

DIGITAL CIRCUIT MODULES

Logic Circuits

Counter Flip-Flop
Power Latch
Power Inverter
Multiple Input "AND" Circuits
Multiple Input "OR" Circuits
Delay Line

Pulse Generation and Amplification Circuits

Power Driver
Indicator Driver
Clocking Pulse Generator

Data Handling Circuits

Write Amplifier
Read Amplifier
Read Head Selector
Read Head Diode Assembly
Core Register Assembly
Core Driver
Decoding Matrix

Housing

Card Cage With Locking Bar

ANALOG BUILDING BLOCKS AND SERVO COMPONENTS

Servo Systems

Rectilinear Servo Motor With Drive Amplifier
Standard Servo Assemblies, AC or DC

Operational Amplifiers

Transistorized Standard Operational Amplifier
Transistorized Low Drift Operational Amplifier
Miniaturized Electronic Tube Operational Amplifier

Buffer Amplifiers

Transistorized Standard Buffer Amplifier
Transistorized 25 Volt Operational Amplifier

Computation Amplifiers

Transistorized Resolver Driver Amplifier
Summing Amplifier, Model 301
Linear Phase Detector
Phase Detector, Model 303

Servo Amplifiers

Transistorized 400 cps Servo Amplifier—20 Watt
Universal Electronic Tube Servo Amplifier, Model 300

Electronic Multipliers

Time Division Multiplier
Sine-Cosine Generator

Write to Dept. ED. Industrial Sales Department, for specific details on the many advantages of *Dialog Components* and *Building Blocks* for systems design.

*DIALOG *(Link Digital-Analog Systems, Components and Building Blocks)*

Another example of Link / Ability

LINK DIVISION
Binghamton, New York

GENERAL PRECISION, INC.
Other Divisions: GPL, Kearfott, Librascope.

CIRCLE 58 ON READER-SERVICE CARD

READ differential or gauge pressure *quickly... accurately... reliably*

Wallace & Tiernan Aneroid Dial Indicators give you fast response, high sensitivity, reliable accuracy.

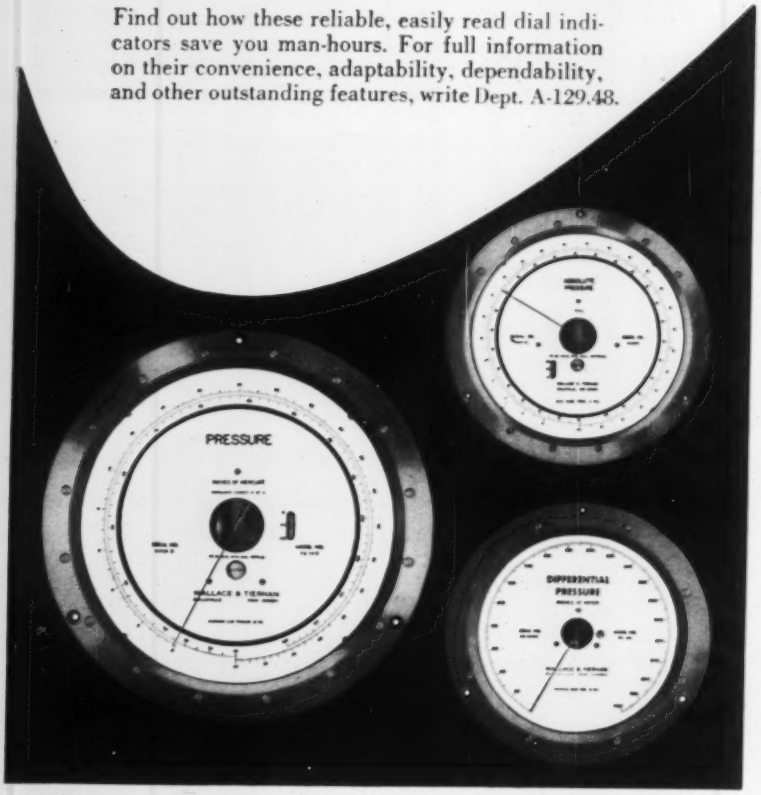
Whether you're in testing, manufacture, or research, there's a W&T Dial Indicator that's ideal over a wide range of differential or gauge pressures.

A W&T Aneroid Dial Indicator guarantees you:

- ★ Accuracy 0.1% to 0.33%
- ★ Sensitivity 0.01% to 0.2%
- ★ Range 0-10" H_2O to 0-500 p.s.i.g.
- ★ Light weight, small size
- ★ Custom-calibrated dial
- ★ No corrections

W&T Aneroid Dial Indicators are also furnished as compound gauges with zero center for measuring both pressure and vacuum.

Find out how these reliable, easily read dial indicators save you man-hours. For full information on their convenience, adaptability, dependability, and other outstanding features, write Dept. A-129.48.



WALLACE & TIERNAN INCORPORATED

25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

CIRCLE 59 ON READER-SERVICE CARD

IGS EVENTS

September 19-21

International Symposium on Data Transmission, Technische Hogeschool, Delft, Netherlands. For information write H. P. Williams, I.R.E., 1 East 79th St., New York 21, N. Y.

September 21-22

Ninth Annual National Symposium on Industrial Electronics, Manager Hotel, Cleveland, Ohio. For information write J. V. Werme, Bailey Meter Co., 29801 Euclid Ave., Wickliffe, Lake Co., Ohio.

September 26-30

Fall Instrument-Automation Conference & Exhibit of the Instrument Society of America, The Coliseum, New York City, N. Y. For information contact W. F. Minnick, ISA, 313 6th Ave., Pgh. 22, Penna.

October 3-5

Seventh Annual PGNS Meeting, Gatlinburg, Tenn. For information write H. E. Banta, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tennessee.

October 3-5

Sixth National Communications Symposium, Utica, N. Y. For information write R. F. Weil, Paul Revere, Turin Road, Rome, N. Y.

October 9-14

American Institute of Electrical Engineers 1960 Fall General Meeting, New York City, N. Y. For information write Clarke S. Dilks, Associate Director, Burroughs Corp., Research Center, Paoli, Penna.

October 10-12

16th Annual National Electronics Conference and Exhibition, Hotel Sherman, Chicago, Ill. For information write Rudolph J. Napolitan, NEC, Inc., 228 N. La Salle St., Chicago 1, Ill.

October 12-14

Fourth Conference on Analytical Chemistry in Nuclear Reactor Technology and First Conference on Nuclear Reactor Chemistry, Gatlinburg, Tenn. For information write D. D. Cowen, Oak Ridge National Laboratory, P.O. Box X, Oak Ridge, Tenn.

October 12-14

Seventh National Symposium of the American Vacuum Society, Cleveland-Sheraton Hotel, Cleveland, Ohio. For information write American Vacuum Society, Box 1282, Boston 9, Mass.

October 14-15

15th Midwest Quality Control Conference, Broadway Hotel, Wichita, Kansas. For information write Howard K. Mitchell, 602 South Brookside, Wichita 18, Kansas.

October 17-19

1960 Symposium on Adaptive Control Systems, Garden City Hotel, Garden City, Long Island, N. Y. For information write F. P. Caruthers, Specialties Inc., Skunks Misery Road, Syosset, N. Y.

October 19-21

Society for Experimental Stress Analysis 1960 Annual Meeting, Hotel Claremont, Berkeley, California. For information write R. F. Stredel, Jr., Engineering Design Dept., University of California, Berkeley 4, Calif.

October 19-26

INTERKAMA, 2nd International Congress & Exhibition for Instrumentation and Automation, Duesseldorf, Germany. For information write German American Chamber of Commerce, 666 5th Ave., N. Y. 19, N. Y.

October 26-27

1960 Computer Symposiums Applications Symposium, Morrison Hotel, Chicago, Ill. For information write Andrew Ungar, Armour Research Foundation, 10 W. 35th St., Chicago 16, Ill.

October 27-28

1960 Electron Devices Meeting, Shoreham Hotel, Washington, D. C. For information write H. W. Welch, Jr., I.R.E., 1 East 79th St., New York 21, N. Y.

October 27-29

Aircraft Electrical Society 1960 Industry Display, Pan Pacific Auditorium, Los Angeles, Calif. For information write McFadden/Charlesworth Co., Inc., 9171 Sunset Blvd., Los Angeles 46, Calif.

October 31-November 4

Current Developments in Automatic Data Processing Systems—Seventh Institute on Electronics in Management, American University, Washington, D. C. For information write Lowell H. Hattery, American University, 1901 F. St., N.W. Washington 6, D.C.

November 1-2

1960 Radio Fall Meeting of the Electronic Industries Association, Hotel Syracuse, Syracuse, N. Y. For information write J. A. Caffiaux, EIA Engineering Dept., Rm. 2260, 11 West 42 St., New York 36, N. Y.

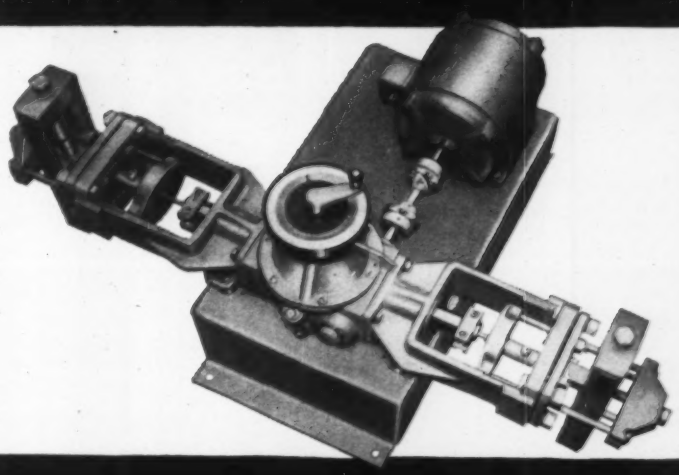
November 14-16

12th Mid-American Electronics Conference, Hotel Muehlebach, Kansas City, Mo. For information write L. R. Crissmon, 10 Richards Rd., Kansas City, Mo.

November 15-17

Northeast Electronics Research & Engineering Meeting, Commonwealth Auditorium, Boston, Mass. For information write E. B. Dunn, Atlantic Refining Co., 260 S. Broad St., Philadelphia 1, Penna.

We Researched Over 15 Industries



Before We Designed This New Pump

From Maine to Texas we explored refineries, paper mills, pharmaceutical and chemical plants. Everywhere we found that metering operations—from pilot plants to proportional blending—were automated, efficient, ingenious. But there was room for an improved plunger pump. A pump that would give more flexibility and convenience in modern metering operations . . . positive accuracy and dependability in metering bland or harshly corrosive liquids against pressure.

Because it's designed around these critical needs, the new Wallace & Tiernan Series 200 Metering Pump fills the bill. Here's how:

Flexibility Drive units may be ganged to meter several liquids. One, two, or three liquid ends on one drive increase capacity and smooth out pumping pulsations. Six stroking speeds, several plunger diameters, and many liquid-end materials add further flexibility. "Stop-Adjust" and "Run-Adjust" models are available. On the latter, automatic stroke-length control, including ratio control, is easily achieved.

Convenience For different capacities or liquids, self-aligning liquid ends are quickly changed as complete units—a real convenience in pilot plant study. Bases for the Series 200 Pump may be steel plate, pipe, or structural shapes. A unique arrangement of eccentrics drives the plunger. This eliminates rocker arms and makes for the responsive, convenient stroke-length control industry needs.

Dependability The Series 200 Pump's design and materials mean resistance to wear and corrosion, less maintenance, and dependable operation. The drive is powered by a standard electric motor. Heavy ball bearings, forced-feed lubrication, and no cantilever bearing loads also assure long-lasting dependability.

Accuracy The Series 200 Pump meters accurately against up to 4,000 psi in the lower ranges (minimum 0.65 gph). And it meters any set amount, time after time, within ±1%—the kind of accuracy modern quality-controlled blending must have.

In every feature, the new Series 200 Pump is designed with modern industrial processing in mind. Component by component and feature by feature, you, the industrial user, called the shots. You specified the new W&T Series 200 Metering Pump.

For more on this user-inspired pump, write today to Dept. L-5.48.

WALLACE & TIERNAN INCORPORATED

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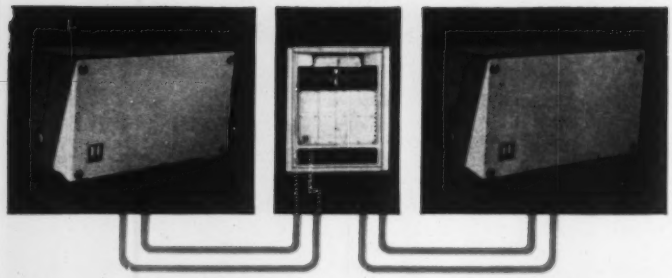


***ElectriK Tel-O-Set*—the true 2-wire system**

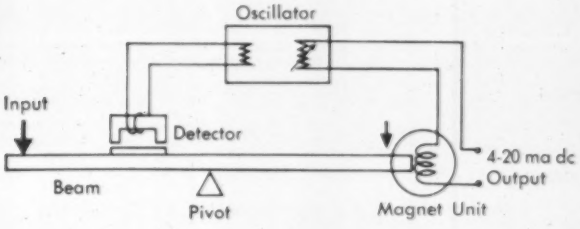
CIRCLE 61 ON READER-SERVICE CARD

Care and feedback of delicate inputs

Delicate inputs thrive on the tender care of *ElectriK Tel-O-Set's force-balance feedback system*. This system, used as the basic circuit in *Tel-O-Set* transmitters, receivers, controllers, and other instruments, has proved itself in thousands of installations in the last five years. The force-balance feedback circuit increases the accuracy and dynamic response of the system by decreasing hysteresis effects and sensitivity to changes in ambient conditions.

Observe: (1) input force (from bellows, Bourdon tube, or displacement linkage) deflects pivoted beam; (2) air-gap in ferrite detector increases, (3) producing a change in inductance in oscillator circuit; (4) a portion of output current is fed back into magnet unit, producing a force on beam which is equal and opposite to input force; feedback balances beam. Full scale motion is only one-thousandth of an inch.

The advanced control engineering seen in force-balance feedback is carried through the entire *ElectriK Tel-O-Set* System. Specifically, there's no external power required at any field-mounted *Tel-O-Set* instrument. Line power connection is made only at the receiver. Two-wire d-c transmission eliminates shielding problems. The 4-20 milliamp signal range of the system gives a live zero and permits the use of the most reliable transistors available. The d-c signals



can be fed into data handling systems and millivolt-actuated instruments . . . can be easily transduced to a standard 3-15 psi pneumatic signal to operate existing pneumatic systems.

Take a new look at your control applications with the *ElectriK Tel-O-Set* System in mind! Get complete technical data from your local Honeywell field engineer. Call him today . . . he's as near as your phone. MINNEAPOLIS-HONEYWELL, 21 Penn Street, Fall River, Massachusetts.

Honeywell

First in Control

SINCE 1885

75th YEAR — PIONEERING THE FUTURE

CIRCLE 61 ON READER SERVICE CARD

CRESCENT

NYLON MULTITUBE

NEW

with INDIVIDUALLY NUMBERED TUBES

NYLON TUBES: TOUGHER AND STRONGER THAN POLYETHYLENE TUBES COST LESS THAN COPPER TUBES

CRESCENT NYLON MULTITUBE employs SPIRALLY CABLED, long-length tubes of black pigmented, heat-stabilized nylon for maximum resistance to environmental deterioration. The SPIRALLY CABLED tubes permit maximum flexibility and bending with no distortion or stress on the tubing.

CRESCENT NYLON MULTITUBE permits greater working pressures and higher operating temperatures than those recommended for polyethylene tubing. The tubes have outstanding impact and abrasion resistance, coupled with unusually high fatigue resistance to flexural and vibrational stresses over a broad temperature range. The tubing is resistant to most chemicals and solvents.

CRESCENT NYLON MULTITUBE is available with 2 to 37 tubes, protected against mechanical injury by a flexible, interlocked, galvanized steel, aluminum or bronze armor. A polyvinyl chloride (PVC) sheath, or a combination of both can be furnished when additional corrosion protection is required. Each tube is individually numbered throughout the length for positive identification of all tubes at any point.

THREE STANDARD TYPES TO MEET YOUR SPECIFIC NEED

TYPE NA— Interlocked, galvanized steel armor provides complete mechanical protection to the inherently corrosion-resistant tubing. Also available with aluminum or bronze armor.

TYPE NAT— Polyvinyl chloride (PVC) sheath over the armor adds corrosion protection for the armor. Can be buried in the earth.

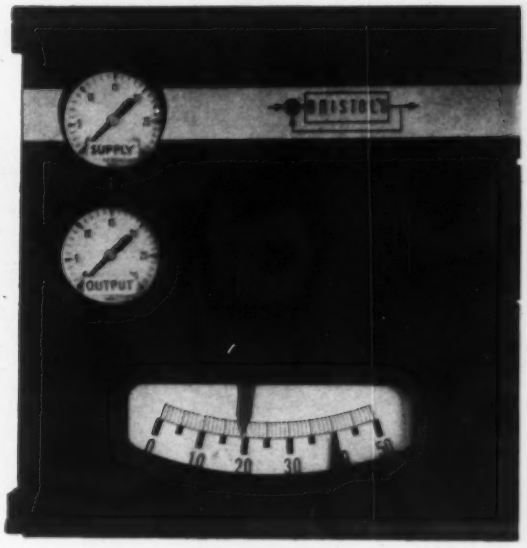
TYPE NT— PVC sheath gives limited mechanical protection. For use in troughs, trays or conduit.

CRESCENT NYLON PRECISION INSTRUMENT TUBING, TYPE N,
is also available in 100-foot coils in cartons
and 500-foot lengths on spools.

CRESCENT INSULATED WIRE & CABLE CO., INC.
TRENTON, NEW JERSEY

CIRCLE 62 ON READER-SERVICE CARD

NEW BRISTOL'S



Series 624 A/D* pneumatic controller features simplicity and high control stability

- **Simple modular design for ease of servicing**
- **High control stability for closer process control**
- **Designed for batch-type and continuous processes**
- **Proportional and proportional-plus-reset control models available**

Top control performance with maximum simplicity plus standard Bristol precision measuring elements—those are the key features of the Bristol Series 624 Controller. The 624 uses the same renowned elements that have earned such a reputation for accuracy and dependability on other Bristol automatic controlling and recording instruments—perfected through wide experience and many years of development.

Self-contained modular design of the control unit speeds servicing. The whole modular unit, consisting of an aluminum casting with working parts made of stainless steel, Ni-Span C, and Neoprene diaphragms, can be removed by taking out only two screws and a link.

Outstandingly compact, the aluminum instrument case (only 8" x 8" x 5" overall) is completely weatherproof. It is designed for either flush, surface, panel, or valve mounting. Attachments for pipe mounting (2-inch pipe) are available. Write for complete data on the versatile and economical 624 A/D. The Bristol Company, 113 Bristol Road, Waterbury 20, Conn. 0.35

Advanced Design

CONTROLLERS OFFERED FOR:

PRESSURE AND VACUUM: Ranges from full vacuum to 10,000 psi.

TEMPERATURE: Ranges from −100°F to +1000°F.

FLOW AND DIFFERENTIAL PRESSURE: With mercury-type manometer and dry-type differential unit.

LIQUID LEVEL: With bulb unit and mercury manometer and dry-type differential unit.

HUMIDITY: Zero to 100% relative humidity.

CONTROL UNIT CHARACTERISTICS:

PROPORTIONAL BAND: 0-400% continuously adjustable, direct- or reverse-acting.

RESET: 0.1 to 50 repeats per minute.

AIR PILOT: Non-bleed type.

PILOT CAPACITY: 3.0 scfm.

FREQUENCY RESPONSE: Flat to 300 cycles per minute.

TEMPERATURE STABILITY: Less than 0.25% change in the output pressure for 90°F temperature change.

MATERIAL: Aluminum housing; 316 stainless steel internal parts; Ni-Span C feedback element.

BRISTOL... for improved production through measurement and control

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

CIRCLE 63 ON READER-SERVICE CARD

TubeXperience in action

SUPERIOR—vast storehouse of "tubeXperience" for producers of measuring, indicating, recording and control devices

With a broad background of experience in producing small-diameter metal tubing to extremely close tolerances, Superior offers instrument makers a wide variety of materials, metallurgical competence, and manufacturing skills that save trial and error in the design stage, besides time and cost in production.

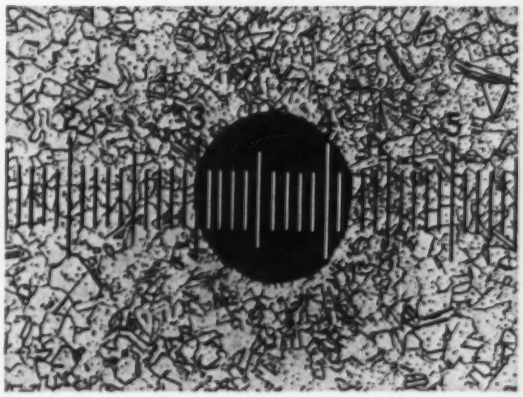
Supplied in over 120 analyses, Superior Tubing is used in virtually every type of measuring, indicating, recording and control device. Wherever it is used, the chances are that some special property required for the application was met from Superior's vast storehouse of "tubeXperience."

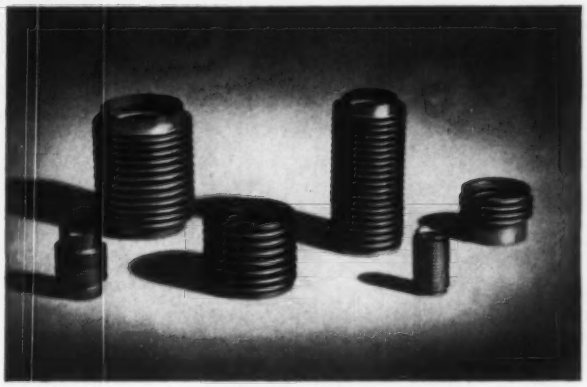
Bulletin 380, "Specialty Tubing for Industrial Instrumentation," gives application data, required characteristics, materials usually specified, range of sizes, tolerances, and other pertinent information on the many types of specialty tubing produced by Superior for the instrument maker. Send for your copy today. Superior Tube Company, 1968 Germantown Ave., Norristown, Pa.

CIRCLE 64 ON READER-SERVICE CARD

Capillary ID size checked under 100x magnification

—yet this critical inspection is only 1 of 3 used to prove ID of Superior capillary tubing. In checking the ID size of capillary tubing we don't rely on only one reading from our inspection microscope, we require four. Then we double-check in two other ways—with a relatively simple plug gage; and a comprehensive flow inspection to ascertain the average ID.



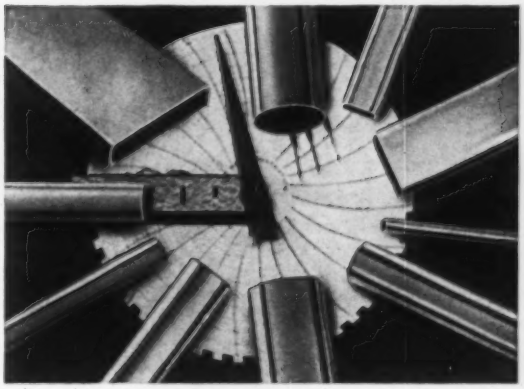


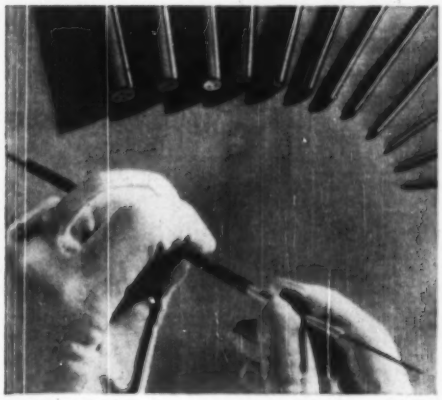
750,000 flexures without failure

—but not an unusual record for bellows formed from Superior thin-wall tubing. Thin-wall tubing of bellows quality—usually under .010 in. max. wall thickness and held to a tolerance spread of only one-thousandth inch—requires the skills and facilities of specialists. It must be extremely ductile—forming pressures can run as high as 5000 psi; brazing can subject it to temperatures up to 1800°F; it must be free of carburization, dents and pickups. We maintain the necessary production standards, employ unique handling procedures, use special controlled-atmosphere furnaces.

Rx for accurate indication of pressure and temperature

—Bourdon tubing by Superior. The tubing from which Bourdon elements are made must be free of carburization or decarburization, rough or corroded surfaces, and variations in wall thickness. It must have good corrosion and drift resistance, also low hysteresis. It must have the extra qualities that permit fabrication of Bourdon elements that are interchangeable in the field with maximum ease, and with only linkage adjustment.





For protection of the equipment and processes it serves

—tubing for thermocouple sheathing must be clean. Tubing with an unusually clean, smooth ID and produced to extremely close tolerances is a prime requisite for sheathing ceramic-pack thermocouples. Also it must be adaptable to temperature extremes (−300 to +2100°F), have high scaling resistance and resistance to shock, fatigue and corrosion. To assure ID cleanliness, Superior recently established a new specification covering this important requirement.

Superior Tube

The big name in small tubing

NORRISTOWN, PA.

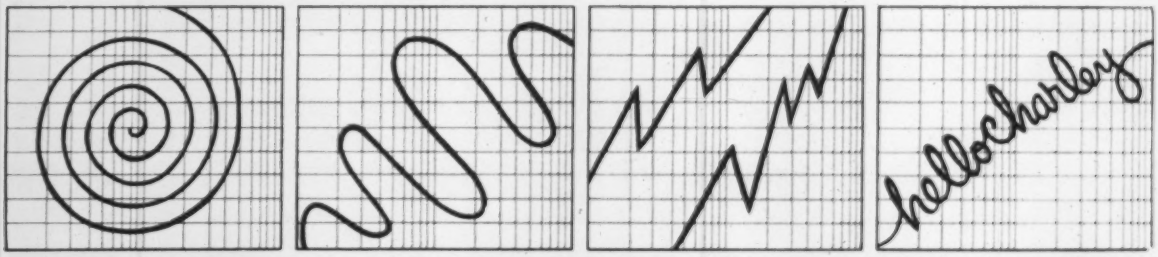
All analyses .010 in. to ⅜ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

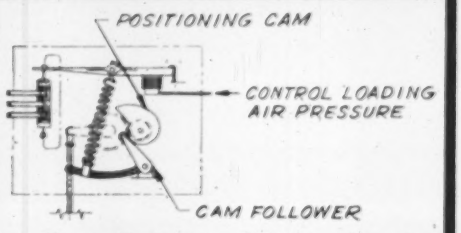
CIRCLE 64 ON READER-SERVICE CARD

Here are some of the curves you CAN'T get with

DeZURIK CONTROL VALVES



BUT YOU CAN GET JUST ABOUT ANY OTHER CURVE YOU'LL EVER NEED!



The positioning cam in the positioner is easily changed to vary the throttling characteristic. Cams can be supplied to produce virtually any desired curve, or they can be cut "on the job" to produce a characteristic tailored to the installation.

Breathes there an engineer with data so precise to permit him to predict positively the required characteristic of a control valve . . . an engineer whose process problems follow a pattern easily solved with a control valve following a standard throttling curve?

If your control valve difficulties present baffling complexities, here's the control valve for you! This DeZurik Control Valve can be characterized right on the job . . . and without replacing any valve parts, without interrupting service, *without opening the valve itself!*

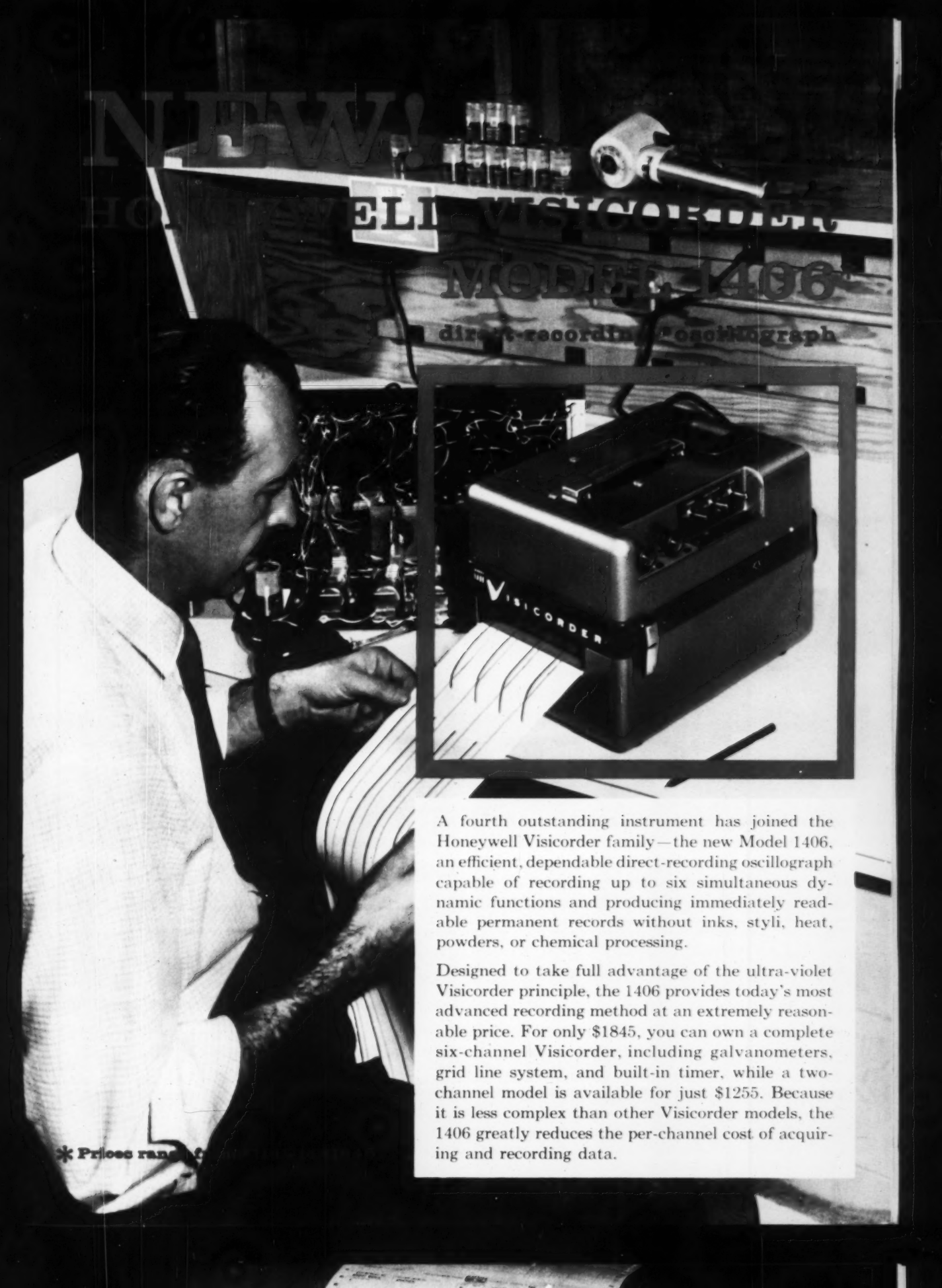
Simply by replacing a cam in the positioner this DeZurik Control Valve behaves in an entirely different way . . . becomes, in effect, a *different* valve!

Get the complete story on DeZurik Control Valves from the DeZurik representative in your area, or write today for Bulletin 150.

DeZURIK CORPORATION
SARTELL, MINNESOTA

CIRCLE 65 ON READER-SERVICE CARD

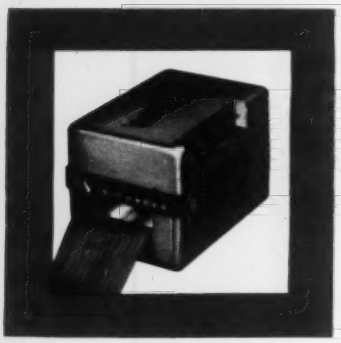
CIRCLE 66 ON READER-SERVICE CARD →



A fourth outstanding instrument has joined the Honeywell Visicorder family—the new Model 1406, an efficient, dependable direct-recording oscillograph capable of recording up to six simultaneous dynamic functions and producing immediately readable permanent records without inks, styli, heat, powders, or chemical processing.

Designed to take full advantage of the ultra-violet Visicorder principle, the 1406 provides today's most advanced recording method at an extremely reasonable price. For only $1845, you can own a complete six-channel Visicorder, including galvanometers, grid line system, and built-in timer, while a two-channel model is available for just $1255. Because it is less complex than other Visicorder models, the 1406 greatly reduces the per-channel cost of acquiring and recording data.

* Prices ran



FEATURES AND SPECIFICATIONS-
MODEL 1406 VISICORDER

Now, for the first time, users whose recording requirements lie in the middle frequency range may obtain genuine Visicorder performance without paying a premium for more sophisticated equipment. Depending upon the galvanometers you choose, the 1406 will record variables with frequencies as high as 200 cps, making it the ideal instrument for the majority of applications as found in normal laboratory testing and evaluation. The 1406 is easily tailored to your individual needs; it may be ordered with a choice of galvanometers and record drive speeds, and is available with or without grid line and/or timing systems. In addition, the new Model 1406 provides many user economies—among them, negligible lamp replacement costs and lower power consumption—than upper frequency range instruments.

Use the 1406 for circuit analysis . . . for current studies . . . for a near-infinite number of other applications which you will discover for yourself. As with all Honeywell Visicorders, the 1406's usefulness and versatility are limited only by the imagination of the user.

GALVANOMETERS—Choice of two natural frequencies: 42 or 330 cycles. L42-700—42 cycles; flat within 10% to 25 cycles; sensitivity 30 ua/in ± 10%; linearity within 5% of full scale deflection (6" peak to peak maximum; 4" single deflection); damping resistance 700 ohm; coil resistance 250 ohm; maximum current 40 ma; may be operated at 500v above ground. L330-120—330 cycle; flat within 10% to 200 cycles; sensitivity 700 ua/in ± 10%; damping resistance 120 ohm; coil resistance 800 ohm; maximum current 30 ma; other specifications same as L42-700.

BANK—Standard C-type magnet in simple adjustable mount. Dummy filler required for use with less than 6 galvanometers; adjustable reference trace optional for either end of bank.

RECORD PAPER—6" x 100' (standard base) or 6" x 150' (thin base). Uses all popular direct-recording papers.

TIME LINES (Optional)—Flashtube system; instant warm up, no parallax. Full width lines at intervals of 1, .1, and .05 sec., 1, .1, and .05 min., or 1, .1, and .05 hr., depending on choice of record speeds.

RECORD SPEEDS—Standard: 25, 5, 1 and .2"/sec. Also available: 25, 5, 1 and .2"/min.; 25, 5, 1 and 2"/hr.; 100, 50, 25 and 5mm/sec.

GRID LINES (Optional)—Choice of inches or metric. .2" spacing; every 5th line heavier for inch ranges; 5mm spacing with every other line heavier for mm ranges.

WRITING SPEED—to 3500"/sec.; STATIC TRACE WIDTH—.03"; OPTICAL LEVER—30cm (11.8"); RECORDING WIDTH—6" maximum; LAMP—70 watt incandescent; LAMP LIFE—rated 100 hrs. in high intensity position; INTENSITY CONTROL—two-position "high" or "low" switch.

POWER REQUIREMENTS—105-129v AC, 60 cps 200 watt; OPERATING TEMPERATURE 32° F to 135° F; HUMIDITY—98%; ALTITUDE—to 10,000 feet; DIMENSIONS—9" x 9" x 12"; WEIGHT—25 lbs.

NOW- A VISICORDER FOR EVERY RECORDING NEED

Model 906 Visicorder—9068-1, 14 channels; DC to 5000 cps; 9068-2, 8 channels; DC to 2000 cps. Both on 6" paper.

Model 1108 Visicorder—24 channels from DC to 5000 cps on 8" paper. Many automatic convenience features.

Model 1012 Visicorder—36 channels from DC to 5000 cps on 12" paper. The most versatile recording oscillograph ever made.

Write for your free copy of the 36-page Visicorder Applications Manual, a comprehensive, detailed guide book to many varied uses of the Visicorder.

For further information, including detailed price and delivery data, write:

MINNEAPOLIS-HONEYWELL REGULATOR CO. • INDUSTRIAL PRODUCTS GROUP
Heiland Division, 5200 East Evans Avenue, Denver 22, Colorado

Honeywell

ANOTHER DIAMOND JUBILEE PRODUCT FROM HONEYWELL

H Industrial Products Group

Teletype machines help cut costly paperwork

A Teletype machine equipped with a simple sprocket-feed mechanism can handle multi-carbon forms as readily as the more familiar plain paper on which messages are transmitted. Thus distances can be bridged not only with information, but with information that is preprocessed, ready to go to work.

Teletype printers handle a wide variety of multi-copy forms. Moreover, the usefulness of this technique can be further extended with Teletype tape punching and reading equipment—which can capture, store and utilize repetitive data to further mechanize paperwork procedures.

Teletype Corporation manufactures this equipment for the Bell System and others who require the finest in data communications equipment.

Typing Tape Punch

Tape Reader

Send-Receive Page Printer

Automatic Send-Receive Set

FREE Model 28 line folder. Write Dept. 27J, 5555 Touhy Avenue, Skokie, Illinois.

TELETYPE®
CORPORATION
SUBSIDIARY OF *Western Electric Company* INC.

CIRCLE 66 ON READER-SERVICE CARD

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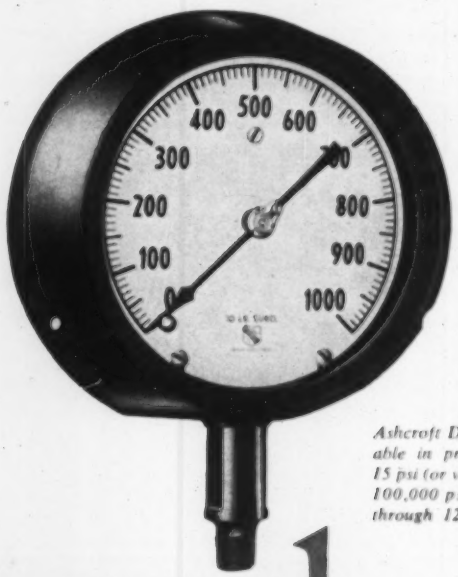
accuracy

ASHCROFT DURAGAUGES measure pressure with precise accuracy no matter how severe the conditions of service



Ashcroft Duragauges are available in pressure ranges from 15 psi (or vacuum) minimum to 100,000 psi. Dial sizes: 4½" through 12".

sustained

The Bourdon tube in Ashcroft Duragauges is manufactured to precision standards of flexibility and mono-linked to the rotary movement. When pressure flexes the tube, the gauge pointer is always positively positioned, because it is mounted on the geared center shaft of the movement. Sustained high accuracy and long life are assured.

Choose your Ashcroft Duragauges made of components best suited to your needs. Eight Bourdon tube materials are available. Movement of stainless steel with nylon bearings and pinion gear for longest wear. Case materials: special aluminum alloy or tough phenol plastic.

The unique "Maxisafe®" Duragauge provides absolute protection to the viewer, plus easy and quick access to the mechanism. Your industrial supply distributor will help you select the best combination of components for your Ashcroft Gauge requirements. Phone him today or write for Catalog 300B.

MANNING MAXWELL & MOORE, INC. TRADE MARK

ASHCROFT PRESSURE GAUGES

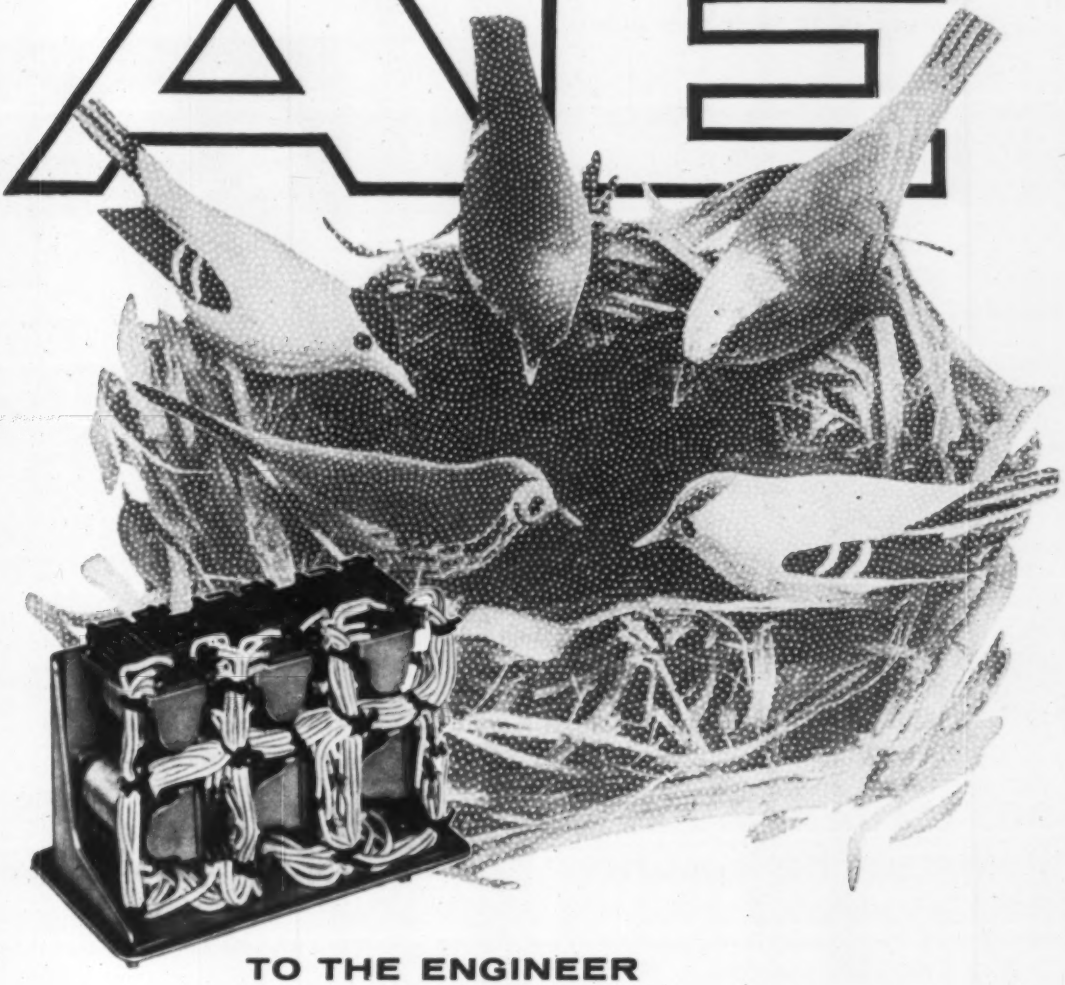
A product of

MANNING, MAXWELL & MOORE, INC.

Gauge and Instrument Division • Stratford, Connecticut
In Canada: Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario

CIRCLE 68 ON READER-SERVICE CARD

AE



TO THE ENGINEER

who thinks "birds' nests" are for the birds...

Upset over the fancy wiring your control package demands? Relax! AE can turn a bird's nest into a thing of beauty *and* high reliability.

The reason is simple: we've had years of experience wiring complex dial telephone switchboards, to say nothing of little black boxes. And we have the techniques down so tidy and pat that our assembly and prewiring costs are more than likely lower than yours.

As a beautiful example, take a look at the compact relay complex illustrated. This custom job is designed to do switching tricks over and over again without failure. A significant part of its dependability is structural rigidity.

AE engineers are also gifted in solving the most complex switching circuits in the simplest and most inexpensive way. Chances are they can save you some headaches.

If you have a control problem, we'd like to hear about it. Just write the Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois. And while you're at it, ask for Catalog 4083-A covering *AE Enclosures for Relays, Switches and Control Systems.*

AE CAN DO

AUTOMATIC ELECTRIC

Subsidiary of

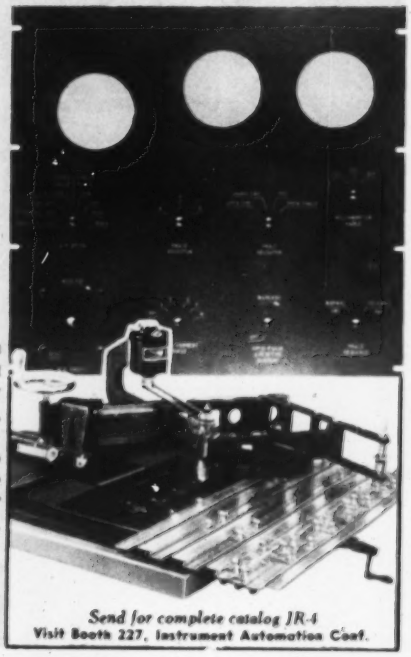
GENERAL TELEPHONE & ELECTRONICS

GENERAL SYSTEM

CIRCLE 69 ON READER-SERVICE CARD

any size panels

engraved in your own plant



Engrave 1-inch nameplates or 6-foot panels by unskilled labor.

Spindle covers 18¼" x 6" in one set-up — more than any other machine of its kind.

Bench type model I-R — $685.

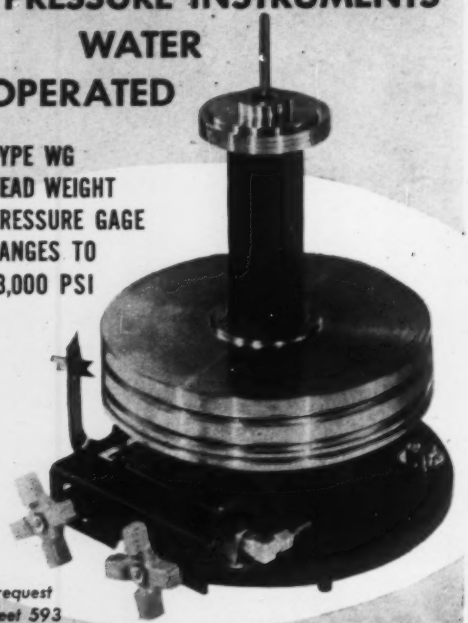
Send for complete catalog JR-4
Visit Booth 227, Instrument Automation Conf.

new hermes *Engraving Machine Corp., 154 West 14th St., New York 11, N. Y.*

CIRCLE 70 ON READER-SERVICE CARD

NO CONTAMINATION OF PRESSURE INSTRUMENTS WATER OPERATED

TYPE WG
DEAD WEIGHT
PRESSURE GAGE
RANGES TO
13,000 PSI



Please request data sheet 593

MANSFIELD & GREEN INC.

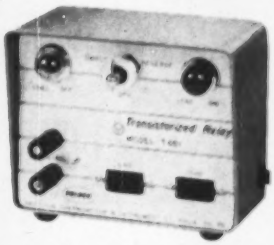
1051 POWER AVE. • CLEVELAND 14, OHIO

CIRCLE 71 ON READER-SERVICE CARD

NEW! FROM PRINCO

A SMALL TRANSISTORIZED RELAY FOR BIG JOBS

Controls loads up to 1500 watts at 110 volts



This Supersensitive PRINCO T-681 relay offers many advantages in size and performance.

1. Small size, light weight—only 3" x 4" x 5", weighs 30 ounces.
2. Transistorized Circuitry—no tubes or batteries to replace.
3. High Temperature Operation—thermistor compensation permits operation in ambients to 120°F.
4. Provides Activating Current of 15 Microamperes, controls loads to 1500 watts.
5. Higher Input Sensitivity—operates through as much as 250,000 ohms across input terminals.
6. Switch lock gives positive control of normally open or normally closed loads.
7. Shock and vibration resistant, mounts in any position.

The T-681 is designed for rugged, long lasting operation with thermostats, thermoregulators and other applications where a highly sensitive, extremely dependable relay is required for microampere operation.

For further information or bulletin,
WRITE, WIRE OR PHONE

Precision Thermometer and Instrument Co.

1434 Brandywine St., Phila. 30, Pa. Phone LOcust 3-6671

CIRCLE 72 ON READER-SERVICE CARD

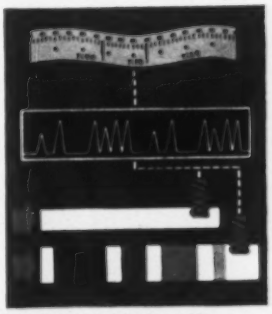
to achieve greater accuracy and flexibility in process stream analysis . . . MSA brings tape programming to Gas Chromatography

A tape-programmed control unit is the key to improved accuracy and flexibility in MSA's new Gas Chromatograph. It's the first of its kind to be used for this purpose. System consists of a motor-driven transparent film in conjunction with a photoelectric transmitter and receiver to provide any combination of time and sequence required.

The tape is a single continuous loop of standard 16-mm film. It's printed in 1-second graduations. Setting up a program is simple: just mark the tape with a lead pencil at appropriate intervals. Repeatability is to within 1/10 of a second.

Here are some other features of the new M-S-A® Gas Chromatograph: analyzer temperature is controlled to within .03°F; a three position function switch permits rapid change from bar graph to spectrum presentation or manual operation; and the analyzer unit can accommodate two columns each up to 50 feet in length.

Write for new tell-all bulletin on this new chromatograph.



See us at the Instrument Show . . . Booth 1718-24

INSTRUMENT DIVISION
Mine Safety Appliances Company
Pittsburgh 8, Pennsylvania

MSA

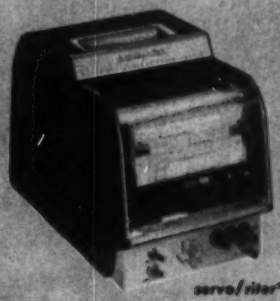
MSA backs up its label with selection, quality, research, experience

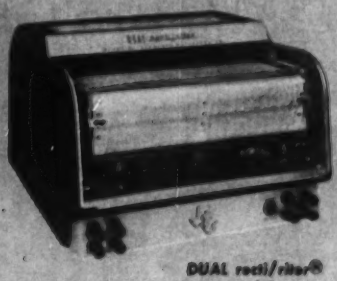
CIRCLE 73 ON READER-SERVICE CARD

from T/I

INDUSTRY'S MOST COM

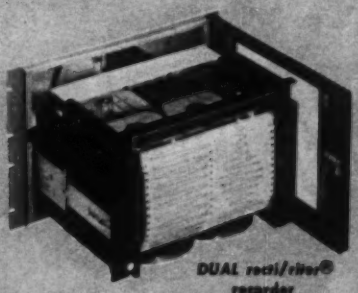
GALVO and SERVO PORTABLE

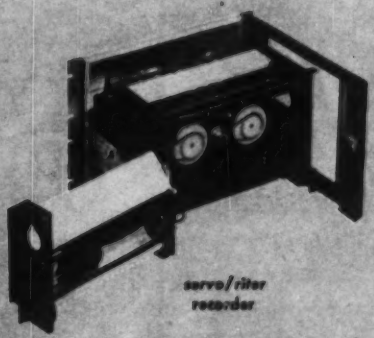




Both ***recti/riter®*** and ***servo/riter*** recorders are offered in convenience-packed portable models with all routine adjustments and controls at your fingertips. ***recti/riter®*** recorders are offered in the widest available d-c and a-c milliampere, ampere, and voltage ranges; expanded scale a-c voltage ranges; and frequency ranges. ***servo/riter*** recorders are available with electrical spans from 1 to 100 millivolts d-c with span step response time less than 0.5 second.

GALVO and SERVO FLUSH-MOUNTING

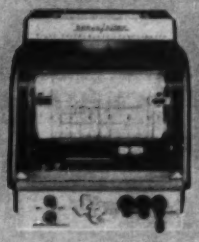




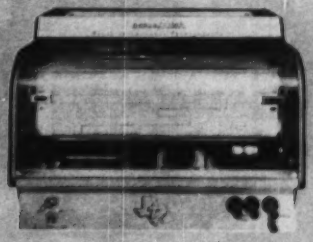
The same industry-proved performance characteristics and wide ranges offered in portable models are also available in ***recti/riter®*** and ***servo/riter*** flush-mounting recorders . . . plus such convenience features as: Chassis rolls out and quickly disconnects for maximum ease in installation and adjustment; illuminated scales and pointers maintain high readability regardless of room light level; swing-open chart carriage permits easy paper handling; advanced design eliminates chart drive gear train lash.

SINGLE WIDE DUAL | CHARTS

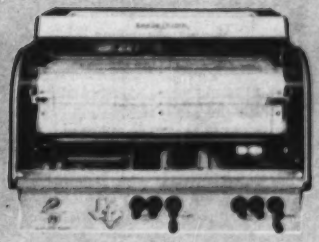
(Portable or Flush)



recti/riter® or ***servo/riter*** recorders: Single Channel, Narrow Grid (4.5-inch grid, 6-inch chart).



servo/riter recorder (only): Single Channel, Wide Grid (9.75-inch grid, 11¾-inch chart); or Dual Channel (two overlapping pens), Wide Grid.



recti/riter® or ***servo/riter*** recorders: Dual Channel, Narrow Grids (two 4.5-inch grids, 11¾-inch chart).

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PLETE RECORDER LINE

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RECTILINEAR GALVANOMETRIC RECORDERS

and

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SELF-BALANCING POTENTIOMETRIC RECORDERS

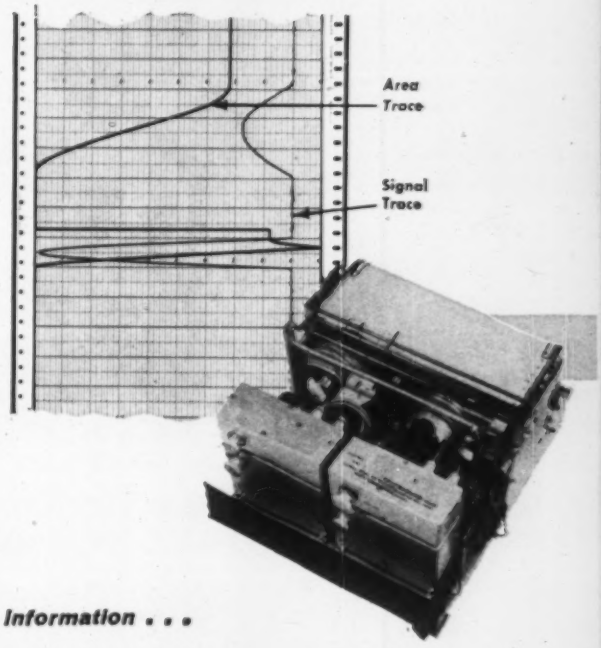
...and introducing the new T/I INTEGRATING RECORDER

Accurate, quantitative analysis of *any variable* that depends on the precise measurement and integration of the curve may be obtained with the TI Integrating Recorder. The integrator channel, installed as a second channel in a standard wide-grid, single-channel *servo/riter* recorder, consists of a special potentiometer-amplifier-servo arrangement and activates an "area trace" automatically and simultaneously with the signal trace.

Five different maximum count rates are readily obtained through an adjustable gear system up to a maximum of 40,000 area counts per minute. The counting rate linearity is ± 0.5% of full scale.

Note that the integrating signal utilizes the full chart scale to provide faster, easier reading. You may reset the pen to either margin between each peak or at the start of each integration for easier interpretation. The integrating circuit may be set to any assumed zero point in the span of the recorder signal.

The new TI Integrating Recorder is particularly oriented toward gas chromatography applications and has more speed and operating flexibility than any other integrating recorder.



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CIRCLE 74 ON READER-SERVICE CARD

Here's why the NEW AO TRACE-MASTER World's finest 8-channel direct writing

American Optical Company, famous for precision instrumentation for 138 years, introduces an electronic direct-writing recorder of unique design, in which ultra-precise electromechanics has been combined with advanced electronics to achieve *truly superior performance.*

Finest Writing Method Ever

TRACE-MASTER uses unique direct-carbon-transfer writing method. Trace is uniformly black and up to four times thinner than that made by any other recorder. Minute variations in phenomena measured are more faithful, more meaningful. Carbon trace is permanent...cannot fade as ink and electric traces do ...may be reproduced by all conventional methods.

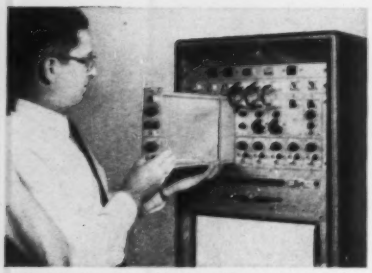
Finest Frequency-Amplitude Performance

TRACE-MASTER'S multiple-feedback wide-range Driver circuitry, combined with the advanced pen-motor design, produces wider frequency response *at larger amplitudes* than any other recorder. TRACE-MASTER response is flat—*within 1%*—from dc to 110 cps at 40 mm!

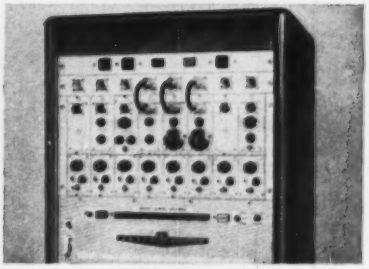
Band Amplitude Product (i.e. Bandwidth times Amplitude) is 5600...140 cps (3 db point) x 40mm! TRACE-MASTER can provide meaningful signal information in areas never before possible with direct-writing recorders!

Finest Chart-Drive Facilities

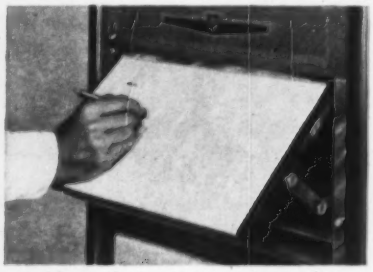
TRACE-MASTER provides widest chart-speed range...0.1 to 500 mm/sec...of any direct-writing recorder! Convenient push-button selection . . . new speed is accurately established before finger can leave the button. Unique take-up reel automatically stores full 1000 ft. record. Writing table tilts to convenient angle for close examination and easy chart annotations. Guide rails permit quick, easy paper-roll changes. Chart paper is low in cost . . . makes it practical to do continuous recording at high speeds for protracted periods.



Entire channel easily accessible and completely interchangeable as single unit.



Compact panel contains all signal input and conditioning facilities.



Platen tilts to convenient writing angle.

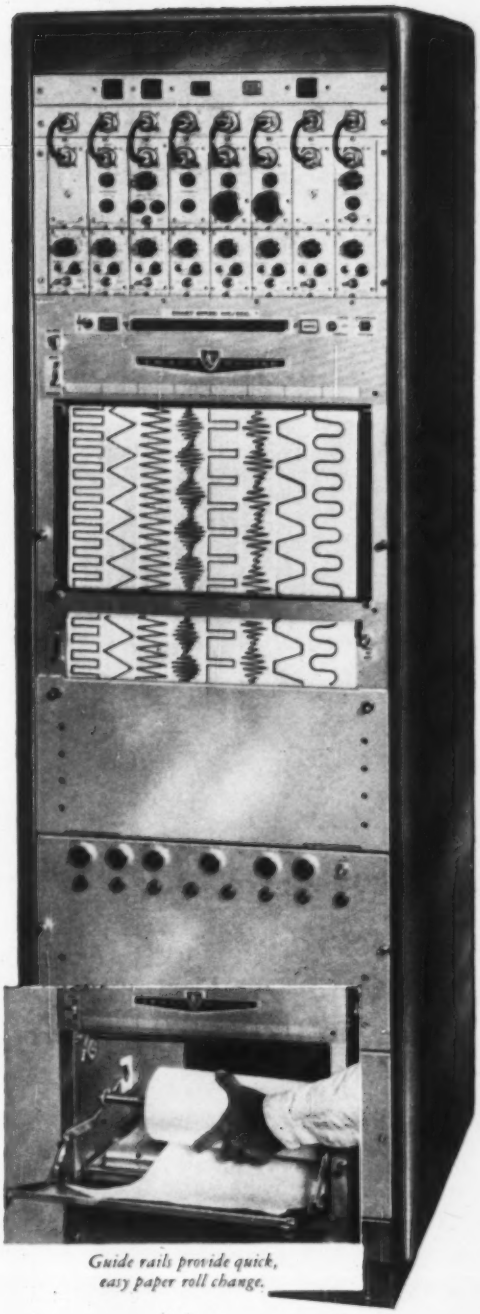
TRACE MASTER

American Optical COMPANY

INSTRUMENT DIVISION, BUFFALO 15, NEW YORK

CIRCLE 75 ON READER-SERVICE CARD

is the recorder!

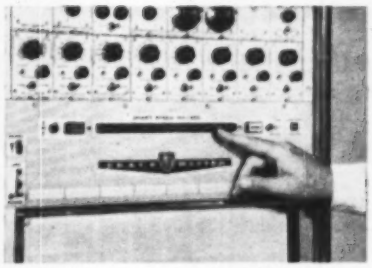


Finest Resolution, Linearity, Stability

Thin carbon trace (thinner by 4 to 1 over most recorders) and high Band Amplitude Product (higher by 6 to 1 over other recorders) provide up to 24 times the resolving power or ability to detect short, sharp variations in the record. The superior linearity (± 1%) and stability in rectilinear presentation permit full use of this unexcelled resolution.

Finest Systems Oriented Compatability

Fully transistorized circuitry . . . generous performance margins . . . conservative derating . . . application of combined dc level and signal multiple feedback . . . complete interchangeability of modular signal-conditioning elements . . . are only some of the outstanding features that combine to make the AO TRACE-MASTER the world's finest general purpose, 8-channel direct writing recorder.



Widest range chart speed . . . push-button selection through 0.1 mm/sec to 500 mm/sec.

Guide rails provide quick, easy paper roll change.

See it . . .

Try it . . .

at WESCON, ISA, NEC, NEREM

Complete TRACE-MASTER systems will be operating at the American Optical booth at all four shows . . . don't miss this opportunity to examine the newest, finest recorder on the market.

Write for Complete Information

Engineering bulletins are now available on the complete AO TRACE-MASTER line of recording modules and systems. Write, wire, or telephone today for a complete file! TRACE-MASTER Field Sales Engineers are at your service everywhere.

Dept. J-283, American Optical Co., Buffalo 15, New York.

Please send engineering bulletins on the New AO Trace-Master.

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CIRCLE 75 ON READER-SERVICE CARD

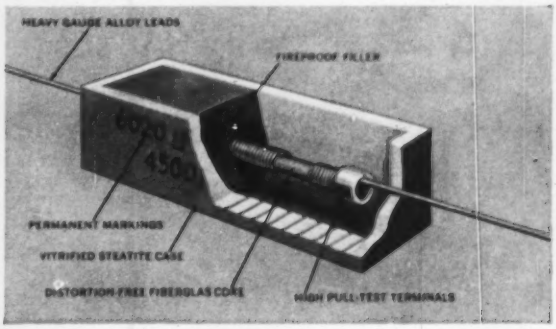
if it's news, expect it first from IRC

Transistor circuits and low power applications need this safety feature!

IRC PW Resistors are available with special resistance windings, designed to act as a standard resistor at normal operating wattages and fuse at some specific overload condition. Thus they provide an ideal solution—resistor and fuse in one unit—a great advantage in circuits which tend to short or where overloading of a component creates a fire hazard.

These double-duty resistors come in six sizes—3, 5, 7, 10, 15 and 20 watts. And, no derating is required even at high ranges.

For additional information on IRC Power Wire Wound Resistors, write for Bulletin P-2, International Resistance Co., 401 N. Broad St., Philadelphia 8, Pa.



IRC

Leading supplier to manufacturers of electronic equipment

CIRCLE 76 ON READER-SERVICE CARD

Are Imports A Threat to American Instrument Manufacturers?

IN 1954 Western Europe and Japan exported $3.5 million of mechanical measuring and electrical instruments to the United States. The figure was $4.5 million in 1955, $7 million in 1956, and grew to $9 million dollars worth in 1957. The dollar value of mechanical measuring instruments accounts on the average for about five-sixths of the total; electrical instruments for one-sixth.

Our exports of such instruments to those same 11 countries ran in dollar value to $60 million in 1954, $62 million in 1955, $78 million in 1956, and $105 million in 1957. The ratio of exports to imports has run in our favor during those 4 years at a rate ranging from 17 to one in 1954, to 12 to one in 1957.

We do have exact figures on 1958 export totals for the industry. Twenty-nine million dollars worth of electrical instruments, and $72 million dollars worth of mechanical measuring instruments were sold abroad last year. Those figures add to total of $101 million dollars worth of exports for this industry, and show that your overseas sales were off about 4% from 1957's high of $105 million. A drop of only 4% in overseas sales for the industry actually compares very favorably with the over-all drop of 14% in total United States exports last year.

For the industry, the current ratio of exports to imports is probably about 10 to one, and the estimated increase is exports, in absolute terms, has been about 6 to 7 times greater than the increase in imports. That is a record in which the instrument industry can take pride.

The statistics indicate that the industry gains far more by trade than it loses. Why then is there the general concern that the impact of imports will damage the domestic economy, including those industries which make up the Scientific Apparatus Makers Association? I believe the answer is to be found in certain relatively isolated cases where a sudden or steady increase in imports has caused real pain and damage to a few companies.

This impact is manifest most severely in the case of some consumer-type goods. For example, in fields related to instruments, I might refer to such items as watches and clocks; still cameras; opera and field glasses; binoculars and telescopes. In each field, we have worked closely with the industries involved, but with varying results. Similarly, we are working at present with producers of medical, surgical, dental, and opthalmic goods; laboratory glass and ceramic ware; but, in each instance, if our efforts are to accord satisfactory results, the impact of imports must be conclusively supported by factual data as to unemployment, decline in production, domestic and foreign distribution, or as to the impact upon National Defense Preparedness.

Your Government endeavors to keep cases of injury to a minimum, and, if such injury does occur, has provided means for obtaining relief. Executive machinery is available to impose higher tariffs, or even quota restrictions, on imports from abroad.

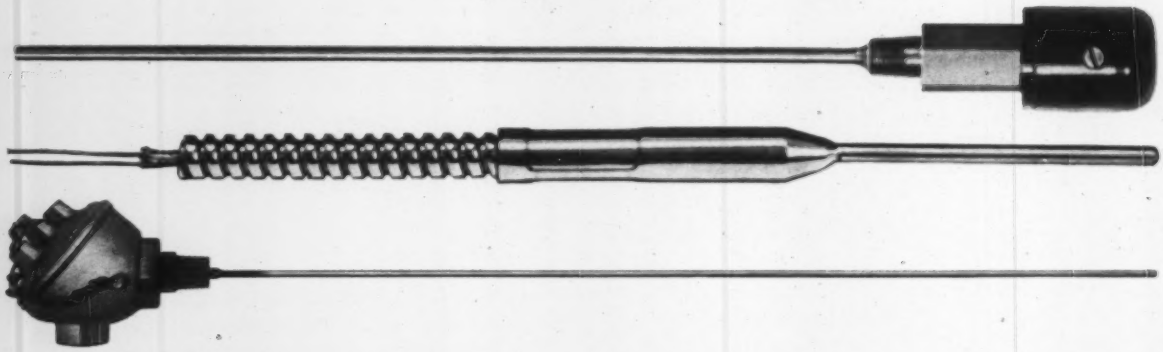
A case in point right now is found in the fears currently being expressed in some circles over the rapid rise in imports of Japanese electronic products, and the action taken by American industry to seek relief. Japanese exports to us of electronic items in the first half of this year exceeded the total for the entire previous year, and nearly trebled the 1957 total. The Electronic Industries Association has asked the Office of Civil and Defense Mobilization to investigate growing imports of Japanese transistors and other semiconductor products, and to take the appropriate action of reporting to the President whether a threat to American security exists.

In other instances, American industry has appealed to the Tariff Commission, which also reports to the President. It is the Commission's duty to specify the so-called "peril-point," which is the rate of duty be-

WALTER A. EDWARDS, Deputy Assistant Secretary for Domestic Affairs, Department of Commerce.

Extract of an address by Walter A. Edwards, Deputy Assistant Secretary of Commerce, delivered at the dinner meeting of the Industrial Instruments Section, Scientific Apparatus Makers Association, The Camelback Inn, Phoenix, Arizona, Tuesday, October 27, 1959.

CHOOSE FROM 150,000 STANDARD *MegopaK* SMALL-DIAMETER THERMOCOUPLES



If you've been looking for small-diameter, flexible thermocouples with high speed of response, search no more. You'll find exactly what you need in Honeywell's *MegopaK** line.

MegopaK is a combination of thermocouple wires, mineral insulation and a protecting sheath, compacted into a solid mass with a diameter as small as 1/16". You can get *MegopaK* in standard lengths up to 25 feet, and in lengths up to 50 feet on special order. They're available with copper-constantan, iron-constantan and *Chromel-Alumel*** calibration. In all, there are more than 150,000 standard combinations of materials and fittings. These top-quality thermocouples are supplied in bulk, and as elements with wires welded into a measuring junction, or as complete assemblies.

MegopaK assemblies come complete with terminations(heads, plugs, etc.) and mounting attachments. Also available are special configurations, tests, material and calibration certifications.

MegopaK thermocouples and other pyrometer supplies are stocked at our Los Angeles and Dallas depots as well as in Philadelphia to give you the fastest possible service anywhere in the country.

Check with your nearby Honeywell field engineer for complete details, or write for Catalog G100-4.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa. —In Canada, Honeywell Controls, Ltd., Toronto 17, Ontario.

*Trademark, Minneapolis-Honeywell Reg. Co.

**Trademark, Hoskins Mfg. Co.

Honeywell

H HONEYWELL First in Control SINCE 1888

75th YEAR PIONEERING THE FUTURE

CIRCLE 77 ON READER-SERVICE CARD

Imports A Threat?

Continued from page 1519

low which, in its judgment, a tariff cannot be lowered without injury to domestic producers. Another safeguard—one written into all United States trade agreements with other nations concerning commodities on tariff schedule—is the "escape clause," under which rates can be raised if imports threaten damage to United States industry. Of course, the President may reject peril-point and escape-clause findings of the Tariff Commission when he believes it is desirable to do so in the National interest, but he is required to submit to Congress the reasons for his action.

Another way of easing the impact of imports is by the method of arriving at gentlemen's agreements between nations. For example, when Japanese output began to boom in several export lines, your Government successfully convinced Japanese manufacturers and exporters that their and our best future interest would be served if they established and abided by reasonable, self-imposed voluntary quotas in some categories of commodities.

Through the use of such Government action and suggestion, we have what I believe is the answer to most potentially harmful impacts of imports on our economy in the future.

I would only add this—trade statistics indicate that the members of this Association have already discovered and put into practice another and equally valid answer. This is to sell to overseas nations more than they sell to us—the potentials for growth in foreign trade are enormous. Experts estimate that the world population will double in the space of 40 years. Even assuming no increase in the world-side standard of living, and assuming that the United States maintains at least its present share of world exports—which has amounted consistently to more than one-sixth of total world exports in the last six years—the population increase alone would add several billion dollars of potential annual export sales.

What does the next decade hold for the industrial instrument makers? To find the answer, we must turn to our Bureau of the Census for some domestic population projections.

The people of the United States will number 215 million in 1970, and 235 million in 1975, say the estimates. That means our population should increase by 30 percent in 15 years. The youthful and aged groups will experience the largest rise. The number of principal workers—those in the middle ranges, from 25 to 45 years old—will remain relatively static during the 1960's.

A relatively larger proportion of our population will be dependent upon a smaller group of production workers. Increased productivity is absolutely essential to maintain—let alone raise—our present living standards.

All signs indicate that the economic health of the world will benefit in proportion to the increased international exchange of needed commodities. Within that framework, it seems likely that our country will over the years adjust more and more successfully to the impact of imports.

Dear D. R.*:

Vacation time is over and it's time to buckle down to work—and your editors have given you a lot of real meat to chew on with this issue. As you know, every issue of *INSTRUMENTS AND CONTROL SYSTEMS* picks out one subject to emphasize via a series of articles—then continues that series for a year or two so that the subject is really covered. As most of these series end up in book form, you readers who miss portions of the series do not lose all. Books to date include:

1. DIGITAL TECHNIQUES FOR COMPUTATION AND CONTROL (the early parts of the digital series which continues monthly in I&CS).
2. STRAIN GAGE INSTRUMENTATION.
3. ELECTRONIC CIRCUITRY FOR INSTRUMENTS & EQUIPMENT.
4. 100 ELECTRONIC CIRCUITS (Vol. 1, Circuits 1-100 and Vol. 2, circuits 101-200)
5. THE COMPUTER HANDBOOK (Vols. 1, 2, 3)
6. THE AUTOMATIC FACTORY
7. PROCESS CONTROL
8. CONTROL VALVES
9. REGULATORS AND RELIEF VALVES.

Series which are now underway for you include:

1. ELECTRICAL MEASUREMENTS (the first portion of this series is available in the HANDBOOK OF ELECTRICAL MEASUREMENTS, available at no cost with a new or renewal subscription to I&CS).
2. WEIGHT INSTRUMENTATION (this series will soon be available in book form.)
3. TIME INSTRUMENTATION (series began in the August issue).
4. MAGNETIC TAPE INSTRUMENTATION (continues in the November issue).
5. METROLOGY—displacement, velocity, acceleration (continues in the October issue).
6. TEMPERATURE INSTRUMENTATION (continues in the November and December issues).
7. VISCOSITY INSTRUMENTATION

But to get back to this issue—it builds on the foundation of the basic ANALOG COMPUTER articles you have received in the past two years. These articles presented the fundamentals of analog computers, including what's behind those holes in the patchboard. Now it is time to show how analog computers are used, and to cover that newest development in the field of analog computer—repetitive operation.

These subjects are covered via a wonderfully practical assortment of articles, showing the use of analog computers, with and without repetitive operation, at various levels. You will also note a new editing technique for presenting the mathematics—each equation is introduced, its meaning spelled out, and its physical significance given. If you think you have forgotten your calculus, you will have a pleasant surprise if you take the time to read the introductions to these wonderful articles. We have long preached that analog computation (simulation) is true "systems engineering"—the technique for obtaining true insight into a system. Here is an issue devoted to a generally neglected subject which should appeal to every person interested in analysis and synthesis of systems.

Milt Aronson

* Dear Reader

E-W Time Code Generator

Model 6190

...Makes time with Atomic Accuracy

Solid State EW Timing Code Generator Uses Atomchron Input

Epsco-West's new Model 6190 Time Code Generator is accurate, flexible, and reliable. In conformance with recommendations of the Interrange Instrument Group (IRIG), the Model 6190 generates a 36 bit 100 pps code, a 28 bit 2 pps code and a 20 bit 1 ppm code. Other outputs are available to drive digital printers, digital tape recorders, strip-chart recorders, oscillograph galvanometers, synchronizing signals and mixed tones of precision frequencies.

The EW Model 6190 is one of a complete line of solid state, modular time code equipment which includes time code generators, time code translators, timing terminals, and universal tape search equipment.

Complete technical information on the Model 6190 Time Code Generator is ready now. Call your nearby knowledgeable Epsco-West engineering representative or address Dept. 54.

Advanced Circuitry Stems From Transistor Know-How

In the Model 6190, all pulse widths and timing are directly derived from the digital dividers and time accumulator by diode matrices. No one-shot circuits are used. Information is not transferred from one register to another. No "stub" counter chains are used. These design features provide absolute synchronism and minimum distortion. Modulation occurs precisely at the true positive going zero-axis point on the carrier.

Epsco-West
First in Data Control
A Division of EPSCO Inc., Cambridge, Mass.

240 E. PALAIS ROAD • ANAHEIM, CALIFORNIA

7

KEY SPECIFICATIONS

Input Signal
100 kc, 1-volt RMS, to impedance of 10,000 ohms. An internal frequency standard may be supplied as optional equipment.

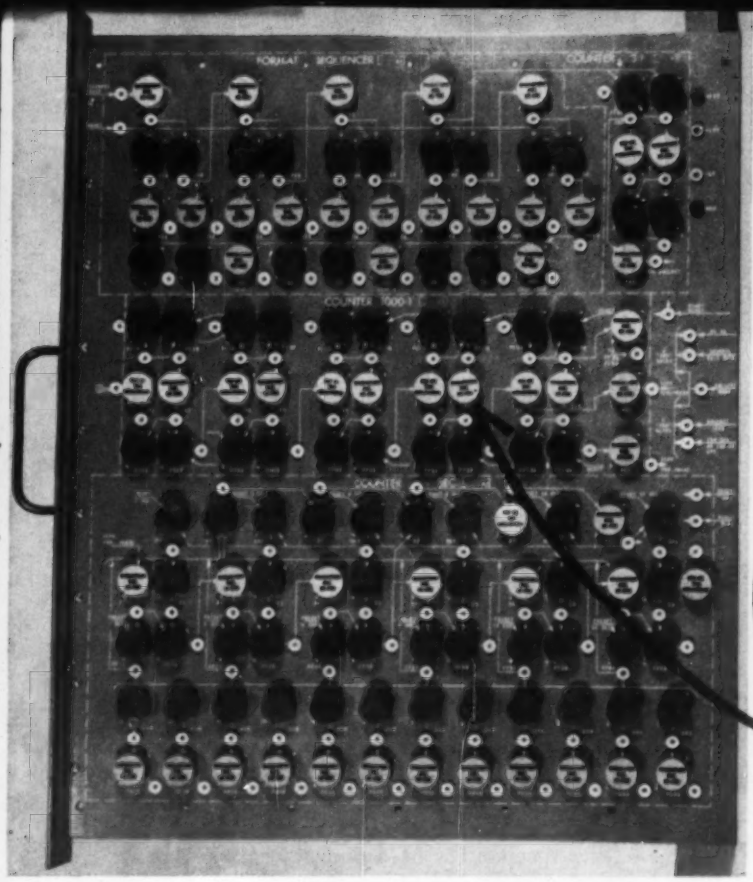
Outputs
1. Logic Output, 36-bit parallel BCD (—12v for binary "zero", 0-volts for binary "one").
2. 20-bit, 1 ppm on 100 cps carrier, 1 hour time frame.
3. 28-bit, 2 pps on 100 cps carrier, 1 minute time frame.
4. 36-bit, 100 pps on 1000 cps carrier, 1 second time frame.
5. Three outputs of the 100 pps, 2 pps and 1 ppm modulation pulses at 2 milliampere max. for driving galvanometers.
6. Relay closure at 1 ppm, 28-bit, 2 pps code, closure for pulse durations.
7. 1 pps at 1-volt, synch pulse, accessible front and rear.
8. 1 pps relay closure of 200 ms.
9. Mixed tones output, 100kc, 50kc, 25kc, 12.5kc, 6.25kc, 3.125kc sine waves.

Elapsed-Time Range
399 days 23 hr. 59 min. 59 sec.

Accuracy
Dependent only on reference oscillator.

Size
19" wide by 10½" high x 18" deep.

CIRCLE 78 ON READER-SERVICE CARD



NOR Logic

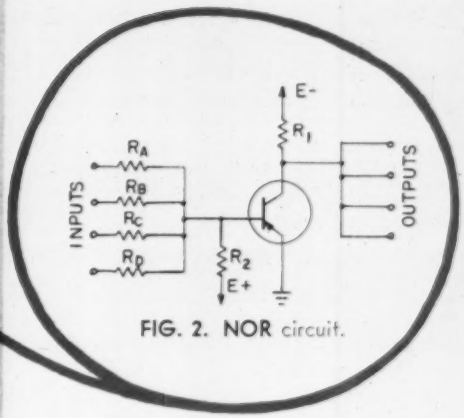


FIG. 2. NOR circuit.

A single transistor element inherently performs NOR logic—that is, it develops a signal only when neither one nor the other of its inputs is present. The NOR element can be operated in such a way that it performs the three basic functions AND, OR and NOT. As it performs the DeMorgan inversion directly, it is a powerful tool for logic.

JOHN BOSWELL

Radiation, Inc.

TABLE I. TRANSISTOR CONDITIONS WITH ONE INPUT.

Input	0	1*
Output	1*	0

* 1 = 5 v signal
0 = 0 v signal

A NOR circuit (Fig. 2) uses a pnp junction transistor operating in the standard grounded-emitter configuration.* The transistor has its collector electrode connected to a negative (−10 volts) supply through a current-limiting resistor (R_1). The base is connected through resistor R_2 to a positive supply (+10v). Under these conditions the transistor is cut off and output is −5v.

If the voltage applied to any input exceeds a predetermined magnitude and is of the proper polarity, it will switch the transistor from its normal cut-off condition to a state of saturation (conducting). Table 1 shows the condition of the element with one input.

When conducting, the output is at ground potential, with excessive currents prohibited by the limiting resistor (R_1). Thus −5 volts appears at the output when no signal is at the input; conversely, a signal (−5 volts) at the input causes 0 volts at the output.

Note that when the element has only one input, it acts as an inverter. When input is 0 (zero volts), output is −5 volts; when input is −5 volts, the out-

*RADILOG nor-logic modules are utilized in sophisticated electronic systems built by Radiation Incorporated, Melbourne, Florida. The company developed the RADILOG family to fill the need for standardization. Three basic modules, each manufactured in three different speeds, accomplish the necessary logic functions.

FIG. 3. RADILOG 1 is an OR gate. Radilog 2 re-inverts signal because radilog 1 inverts when it performs the OR logic.

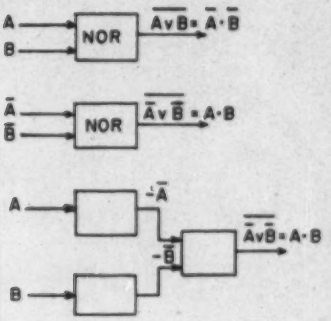


FIG. 4. BASIC NOR element inverts as it performs OR logic. Thus it performs DeMorgan's inversion. Note how the basic logic operations AND and OR are derived from inputs, A, B, $\overline{A}$ and $\overline{B}$.

put is 0 volts. Table 1 can be considered a truth table for inversion.

If two or more inputs are used, the output becomes 0 when *any* input receives a signal (1). Note that the element produces a 1 signal only when *none* of the inputs is present—that is, neither A input, nor B input, nor C input is present. For this reason the element is called a NOR element.

The NOR element can be operated to perform all of the basic logic functions—NOT, OR and AND.

Inversion

As shown in Table 1, the unit inherently inverts the input when only one input is used. Thus a RADILOG with one input is an inverter and performs NOT logic.

OR Gate

Any input of a Radilog which has a 1 signal (—5 v) will switch the transistor on and produce the 0-volt output.

This fulfills the requirements of an OR gate. That is, it switches state when either input A *or* input B *or* input C exists.

However, the output signal sense has been reversed. The input (1) signal is —5 volts; the 0 signal is 0 volt. As the package output is 0 volt when any input exists, it *inverts* as it performs OR. Another Radilog can be used as a NOT element to re-invert the signal, as in Fig. 3. Often this re-inversion package can perform additional logic functions while it returns the signal to the agreed sense.

DeMorgan Operation

The two basic logic operations are AND and OR. Yet expressions involving AND logic can be changed into OR logic, and *vice versa,* by use of DeMorgan's powerful theorem, also known as the involution law, inversion postulate, or dualization law. DeMorgan's theorem states that a logic expression can be inverted simply by (1) inverting each term of the expression, (2) changing each AND element into an OR element, and (3) changing each OR element into an AND element. The proof of this theorem has been shown previously in this series*, and its use shown several times. For example, to invert the expression A v B:

$$\overline{A \vee B} = \overline{A} \cdot \overline{B}$$

To invert A•B:

$$\overline{A \cdot B} = \overline{A} \vee \overline{B}$$

To invert the expression $(\overline{A \vee B}) \vee (A \cdot B)$

$$\overline{(\overline{A \vee B}) \vee (A \cdot B)} = (A \vee B) \cdot \overline{(A \cdot B)}$$

Note in the above that each term in brackets is considered an entity.

The Radilog inverts as it performs OR logic and is, therefore, a device which performs DeMorgan's inversion automatically.

This is shown in Fig. 4, which shows the basic operations of the NOR element.

Binary Adder

The binary addition rules for bits A and B are:

A	0	0	1	1	
+B	0	1	0	1	
Sum	S	0	1	1	0—and carry 1 to next column.

A sum signal exists when *either* A *or* B is present. This is (as shown previously):

$$S = A \cdot \overline{B} \vee B \cdot \overline{A}$$

The truth table for the sum and carry digits is given in Table 2, which also develops the general logic statement for the existence of a sum signal and a carry signal, including the carry signal from a prior operation (C_p).* When there is no carry, as when adding the first column of digits,

$$S = A \cdot \overline{B} \vee B \cdot \overline{A}$$

*See article "Addition and Subtraction by Symbolic Logic," by Brooks, *I&CS*, April, 1960.

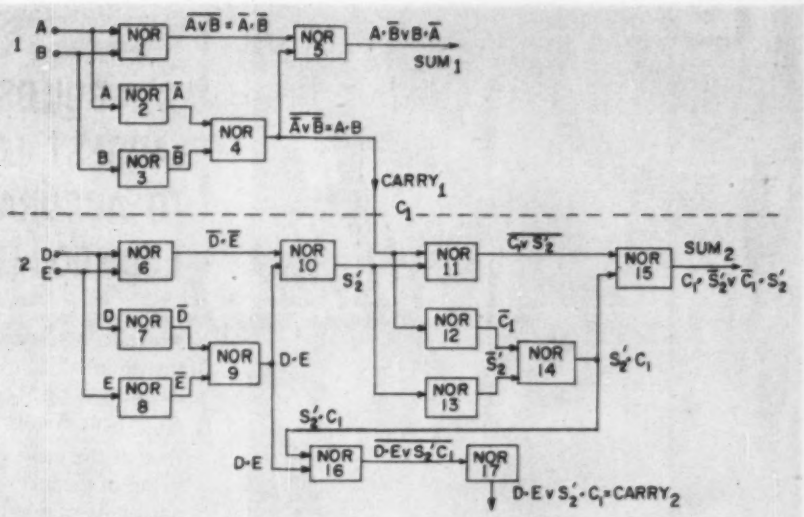


FIG. 5. BINARY adder. NOR elements 1-5 develop the first sum and carry; elements 6-10 develop the subtotal and carry; elements 11-15 add the subtotal and previous carry.

This type of statement is called an *exclusive OR*. S exists when either A or B exist, but not when both A and B exist. Thus it also can be expressed:

$$S = (A \vee B) \cdot \overline{(A \cdot B)} = A \cdot \overline{B} \vee B \cdot \overline{A}$$

In like manner the carry signal can be deduced from Table 2. There is only one possibility for developing a carry output when there is no carry input from previous operations—that is, when both A and B exist.

$$C = A \cdot B$$

A binary adder made up of Radilogs is shown in Fig. 5. The top half of the drawing develops the sum and carry signal for the first column of binary digits; the bottom half for the second column, etc. Additional sections (similar to the bottom half of Fig. 5) can be connected in sequence to handle the desired number of columns of digits.

At the top of Fig. 5 the output of NOR 1 will be $\overline{A \vee B}$ (zero). The output of NOR 2 is $\overline{A}$, that of NOR 3 is $\overline{B}$.

Hence the output of NOR 4 is $A \cdot B$, as shown. This is the desired carry signal, by definition.

The output of NOR 5 is $A \cdot \overline{B} \vee B \cdot \overline{A}$, which is the desired sum signal.

The bottom half of Fig. 5 shows an adder circuit that can accept a carry signal from the lower-order column of bits. Here inputs D and E represent the bits of the second column to be added. We want a sum signal on output 2 for the four sum conditions shown in Table 2, and a carry signal for the four conditions shown for the carry. NOR elements 6, 7, 8, 9 and 10 develop a subtotal and subcarry due to D and E—that is, S_2 will exist if D and E exist, but not if both are present.

NOR elements 11, 12, 13, 14, and 15 develop the desired sum signal by adding the subtotal and the carry from the previous column. This can be expressed as:

$$(C_1 \vee S_2') \cdot (C_1 \cdot S_2') = C_1 \cdot \overline{S}_2' \vee S_2' \cdot \overline{C}_1$$

But $C_2' = D \cdot \overline{E} \vee E \cdot \overline{D}$

Substituting: Output 2 =

$$C \cdot (D \cdot \overline{E} \vee E \cdot \overline{D}) \vee (D \cdot \overline{E} \vee E \cdot \overline{D}) \cdot \overline{C}_1$$

TABLE 2—TRUTH TABLE AND EQUATIONS FOR SUBTRACTION. EQUATIONS EXPRESS THE CONDITIONS SHOWN TO BE TRUE BY THE TABLE.

Inputs			Output		S exists when	C exists when
A	B	C_p	S	C		
0	0	0	0	0		
0	0	1	1	0	$\overline{A} \cdot \overline{B} \cdot C_p$	
0	1	0	1	0	$\overline{A} \cdot B \cdot \overline{C_p}$	
1	0	0	1	0	$A \cdot \overline{B} \cdot \overline{C_p}$	
0	1	1	0	1		$\overline{A} \cdot B \cdot C_p$
1	0	1	0	1		$A \cdot \overline{B} \cdot C_p$
1	1	0	0	1		$A \cdot B \cdot \overline{C_p}$
1	1	1	1	1	$A \cdot B \cdot C_p$	$A \cdot B \cdot C_p$

$$S = \overline{A} \cdot \overline{B} \cdot C_p \vee \overline{A} \cdot B \cdot \overline{C_p} \vee A \cdot \overline{B} \cdot \overline{C_p} \vee A \cdot B \cdot C_p$$

$$C = \overline{A} \cdot B \cdot C_p \vee A \cdot \overline{B} \cdot C_p \vee A \cdot \overline{B} \cdot C_p \vee A \cdot B \cdot \overline{C_p}$$

Applying DeMorgan's theorem two times to the second term:

$$\overline{D \cdot \overline{E} \vee E \cdot \overline{D}} = \overline{(D \cdot \overline{E})} \cdot \overline{(E \cdot \overline{D})}$$
$$= (\overline{D} \vee E) \cdot (\overline{E} \vee D)$$
$$= E \cdot D \vee \overline{E} \cdot \overline{D}$$

Therefore output 2 =

$$C \cdot (E \cdot D \vee \overline{E} \cdot \overline{D}) \vee (D \cdot \overline{E} \vee E \cdot \overline{D}) \cdot \overline{C} =$$
$$E \cdot D \cdot C \vee \overline{E} \cdot \overline{D} \cdot C \vee D \cdot \overline{E} \cdot \overline{C} \vee E \cdot D \cdot \overline{C}$$

This fulfills the sum condition.

To develop the proper carry, it is necessary to realize the four conditions shown in Table 2. This is done by combining the carry from D and E and that from S_2' and C_1, as shown in Fig. 5.

The output of NOR 16 is

$$\overline{D \cdot E \vee S_2' \cdot C_1}$$

Nor 17 inverts this to

$$D \cdot E \vee S_2' \cdot C_1$$

Substituting $D \cdot \overline{E} \vee E \cdot \overline{D}$ for S_2':

$$\text{Carry} = D \cdot E \vee (D \cdot \overline{E} \vee E \cdot \overline{D}) \cdot C_1$$
$$= D \cdot E \vee D \cdot \overline{E} \cdot C_1 \vee E \cdot \overline{D} \cdot C_1$$

This fulfills the carry conditions because D·E

$$= D \cdot E \, (C \vee \overline{C})$$
$$= D \cdot E \cdot C \vee D \cdot E \cdot \overline{C}$$

BLH BUILDS WORLD'S LARGEST LOAD CELL TO ACCURATELY MEASURE 1,500,000-LB. ROCKET THRUST

America's first rocket engine with a launching thrust of 1.5 million pounds is now being developed by Rocketdyne, a division of North American Aviation, Inc.

One of the most critical factors in the successful firing of a rocket or missile is the exact determination of weight and thrust. Present operational rocket engines are tested for weight and thrust by using a series of load cells of no more than 100,000 pounds capacity each, along with allied instrumentation for computing data from the several sources.

Now the BLH development of a single functional cell with a 1.5 million lb. capacity will permit evaluation of total weight and thrust from one source, reducing the number of possible sources of error. Calibration and testing by the National Bureau of Standards has proved the load cell and its instrument system to be accurate to ±0.10% of reading over the full scale from one-tenth to full capacity. The complete system will become part of Rocketdyne's high-thrust test area at Edwards Air Force Base, Calif.

BLH experience and capabilities in force and strain measurement are available for your use, whether in pioneering efforts such as this one, or in the improvement of existing measurement applications. Write for additional proof of BLH capabilities . . . or contact your nearby BLH sales engineering representative for application engineering service.

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Infrared Radiometry

Infrared radiometry is becoming a powerful tool for measuring minute temperature differences and temperatures at a distance. Here is a state-of-the-art survey of the optical materials used, the detectors available, and applications — industrial, meteorological, and military.

RICHARD K. McDONALD, Boeing Airplane Company

THERMAL RADIATION is such a universal property of matter that it only is absent when the matter is a monatomic gas like helium, or is at absolute zero temperature. Symmetrical diatomic gases such as the nitrogen and oxygen in air are for practical purposes also non-emitters of heat energy.

A *radiometer* directly measures the radiant energy emitted by a body. In many cases this is sufficient information; but frequently the desired quantity is the actual temperature of the emitting surface. Then one must know how much heat has been absorbed by the intervening atmosphere, and something of the object's ability to emit radiation. This latter quality is termed *emissivity*. It represents the ratio of emitted energy to the theoretical maximum radiated by a black body at the same temperature.

Most natural materials, excluding metals and certain transparent substances, have emittances greater than 0.9 in the infrared. Even human skin has a high emissivity of 0.95. Metals can have emissivities as low as 0.02.

By relating the character of the test surface to a black body, we are able to utilize certain well-known thermodynamic laws. One law, Stefan-Boltzman's, says that the quantity of radiation is proportional to the area and the absolute temperature raised to the fourth power. Another, Planck's Law, predicts the spectral distribution of the energy as a function of temperature. The principal feature to remember about Planck's Law is that the cooler an object, the longer will be the wavelength of peak spectral intensity. At higher temperatures the change can be observed visually as when an incandescent body changes from white to red upon cooling. After the surface cools further, the wavelength of maximum intensity shifts to 5.4 microns at 500°F, and 10 microns at room temperature (one micron $= 10^{-4}$ centimeters).

Even a gas follows these radiation laws, except it would only be "black" at the wavelengths of its particular emission bands.

The spectral region of most significance to radiometry—two to fifteen microns—coincides with that of greatest value for infrared absorption spectroscopy. Loss of atmospheric transmission at these wavelengths is caused by light scattering

TABLE 1—CHARACTERISTICS OF INFRARED DETECTORS

Type	Detector	Cutoff Wavelength (Microns)
Thermal	Thermistor bolometer	Flat response
	Thermocouple	Flat Response
	Golay Cell	Flat response
Photoconductive	PbS	3
	PbSe	6
	PbTe	5.5
	InSb	5.5
	P-type Ge (Au)	9
	Ge-Si (Zn, Sb)	14
	Ge (Cu)	30
	Ge (Zn)	40
Photovoltaic	InSb	5.5
	InAs	3.7
Photoelectromagnetic	InSb	7
Photographic Film		1.3
Photoelectric Photomultiplier		1.2
Human Eye		0.8

from clouds and smoke, and molecular absorption by water and carbon dioxide. Despite popular impressions, infrared is blocked by clouds to about the same extent as visible light.

IR Optics

Transforming radiant heat into usable information involves many elements akin to man's sense of sight. Just as with the eye, the radiometer has an optical system, detectors which generate electrical pulses, an electrical transmission network, and finally some sort of display like a meter or picture. All of this can be made so compact that an entire assembly, including a 4″ telescope, can be held in one hand.

Since infrared is propagated in the same manner as light and obeys the same optical laws, there is little difference between their optical systems. A difference does exist in the manner of emphasis; reflecting telescopes are far more popular than refracting types. More use is made of the new optical tricks such as light pipes for transmission around corners, or hollow polished cones to condense the energy onto a smaller detector. Generally, dimensional tolerances for surfaces are less critical in the infrared than for the shorter wavelengths of visible light. Consequently radiometers with optics larger than 12″ diameter and f/ numbers less than f/2.0 are not unusual.

Although the infrared spectroscopist for over 75 years has been advancing his science with the only available transparent media, natural crystals, these are undesirable for field equipment. Within the last six years, production of some singular new materials has removed many of the earlier optical design barriers. We now can choose from unique glasses made of *arsenic trisulfide, fused quartz, calcium aluminate, magnesium fluoride, and selenium;* or from crystalline dielectrics such as *sapphire;* or from crystalline semiconductors, *silicon* and *germanium*. At present sapphire can only be produced in sizes up to about six inches in diameter, silicon to 12 inches, and fuzed quartz to 18 inches. Larger sections are expected in time.

As a footnote to history, an empirical observation was recorded in 1870 on the excellent heat transmission of visually opaque *arsenic trisulfide*. Not until 1949 did anyone again recognize the value of the glass in published literature. Today this substance is the one most generally used for large radiometer windows.

Glass has the advantages over crystalline compounds of being less expensive, easier to fabricate, and more suitable to large complex shapes in unlimited production. Unfortunately, those glasses which can transmit in the infrared usually have poorer mechanical or chemical properties than conventional glass.

The metallic luster of *silicon* and *germanium* belies their utility in the infrared. Were it not for the high cost and size limitation, silicon would be the most versatile infrared optical material, thanks to its light weight, strength, stability, and excellent transmission beyond 1.2 microns. Size limitations have been overcome by constructing mosaic-like domes of many small panes. An aggravating problem arises when silicon becomes warmer than about 400°F; the window becomes completely opaque. Crystals of dielectrics such as quartz, sapphire, and periclase (magnesium oxide) do not suffer at this temperature.

The performance of an infared system will be diminished if the window becomes hot because radiation from the window itself may saturate the detector, or obscure the real target signal. From this standpoint, *periclase* would be the ideal optical material, because theoretically it has the lowest emissivity. However, the supply for optical-quality crystals is only from the accidental condensations on the walls of a furnace which makes powdered magnesium oxide.

Detectors

Until World War II, the only detectors having IR response were the so-called "thermal detectors" (Table 1). By change in thermo-electric potential or electrical resistance, the temperature rise of the detector when it is exposed to the radiation is measured. About fifteen years ago, thermocouples with time constants of one hundredth of a second were produced; now, cells have appeared with ultrafast (one-tenth of a microsecond) time constants.

From the technological breakthrough in the field of *semiconductors* have come infrared detectors of vastly improved performance (Table 1). These can be subdivided into classes according to the manner in which the number of free, internal electrons caused by the absorption of light are measured. The type which shows a change of current when

illuminated is called a *photoconductor*. Those whose voltage output changes are *photovoltaic cells*. The third class, known as *photoelectromagnetic detectors*, responds with an electric potential if an external magnetic field is present.

New or improved detectors are appearing regularly; more lead-sulfide cells are used than all others put together.

Because they are usually based on true quantum reactions, modern detectors are much faster than thermal types and will show a sensitivity cutoff at some characteristic wavelength. (Table 1).

The farther into the infrared that a quantum detector responds, the more important it is to cool the detector. Lead sulfide with about 3-micron cutoff is excellent at room temperatures; but lead telluride with sensitivity to 5.5 microns must be taken to −320°F (liquid nitrogen temperature), and the zinc-doped germanium cell responsive out to 40 microns is only practical at −423°F (liquid helium temperatures).

Obtaining liquid nitrogen temperatures is not a formidable problem. Cryogenic systems have been reduced in weight and complexity to the point where even small guided missiles can capitalize on the improved performance of cooled cells.

Thermal Imaging

An exciting aspect of modern infrared is *thermal imaging*. This is not infrared imaging by reflected infrared, in the sense of the "Sniperscope," but in a completely passive manner. A human can be seen by his own body heat when we use equipment sensitive to wavelengths longer than five microns. Two "cameras" are now commercially produced with this performance.

One projects an image of the target upon a blackened membrane which is coated with a thin oil film on the reverse side. Where the image is the hottest, optical interference techniques will show the thinnest oil film. (Imaging by differential evaporation was first used in 1840 when John Herschel examined the solar spectrum with alcohol-soaked black paper.)

The other instrument is more suitable to quantitative data reduction. Here a conventional radiometer is mechanically mounted so as to scan, line-by-line, across the field of view. By a three-step process, a photograph is obtained which is a translation of the detector output into various shades of gray onto the film.

Both of these commercial cameras are only adaptable to stationary objects due to slow frame rates. The development of faster electronic imaging tubes has reached pilot-plant production status. These will look at a large field of view 30 times per second and eliminate much of the complexity of present-day mechanical scanning systems.

Many unusual heat-detection principles are being explored for application to infrared imaging tubes. One of the most successful incorporates a mosaic of photoconductors for the heat-sensitive element. Each cell in the mosaic is sampled in turn by an electron beam similar to the process of the vidicon tubes of television use.

INFRARED GAS RADIATION (IRGAR) pyrometer of The Perkin-Elmer Corporation.

Except for some strange intensity contrast, the subjects of thermal photographs are easily recognizable. To the eye, a factory building at night appears to have brightly illuminated windows and black chimneys. To the radiometer, the chimney is the brightest object in sight, while the windows appear darker than even the factory walls.

A favorite demonstration subject is the human. Faces slightly resemble a skull because the sinuses and ears are cooler than elsewhere. Some medical uses have been examined for the infrared camera, insomuch as slight variations in skin temperatures are associated with circulatory ailments and cancerous areas.

Since insulation, or its omission, shows up so clearly, thermal imagers have proved of value at chemical processing plants and power stations which deal in elevated temperatures. No faster way is known for tracing heat flow patterns about an electronic chassis than with an infrared camera. More uses may develop in detecting surface wakes of submarines.

Industrial Applications

Industrial radiometry in America followed a similar limited pattern before 1940. Small direct-current pyrometers for controlling the temperature of furnaces were on the market begining in the early 1930's. Not much else except a few highly specialized meteorological instruments were commercially available. Research radiometers were all homemade.

Through the last fifteen years, the d-c pyrometer

has largely overcome its original faults of temperature instability, slow response, and low sensitivity. A substantial market has grown among metal fabricators and refractory processors for the control of furnaces, soaking pits, or kilns at temperatures between 500°F and 3400°F.

Most of the units are housed in a small cylinder about 4" in diameter and 6" long. They have no moving parts, are relatively inexpensive, and designed for factory environments. Generally, they would be fixed installations, close to a target which does not move or change temperature more frequently than once every second. Their accuracy usually can be relied upon to be within 1% of the indicated temperature.

Since it does not depend on physical contact, radiometry can establish the temperature of moving objects, and objects in radioactive, abrasive, or corrosive environments. Sufficiently fast detectors are available that the heat distribution on the periphery of tires rotating at 100 mph can be followed. Radiometers have solved the problem of determining the operating temperature of tiny machine cutting tools.

Many assembly-line processes make good use of radiometers. One of earliest such applications was to check production of tin cans by the heat from freshly soldered seams. Temperature controllers have been established in steel rolling and paper mills where continuously moving strips are observed.

Outstanding reported new commercial uses for infrared include a device for checking railroad journal-box temperatures, and a fire detector that only responds to the flickering of a flame. Both are highly specialized radiation detectors. The first tackles one of the most vexing irritants of railroading, the "hot box." Sitting unattended alongside the railroad track, it can automatically sense a dangerously heated journal. Simultaneously an alarm and record of the faulty axle are displayed at a manned installation several miles away.

Most fire detectors must be warmed by heated air before they can trigger an alarm. Unlike these, the infrared fire detector only looks for the characteristic flickering of an open flame, which means fluctuations of radiant intensity within the frequency rate of 6 to 30 cps. Its detector is a lead-sulfide cell covered by a hemispherical lens. Another version is adapted to combustion flame control. Ordinary thermostats cannot adequately distinguish between the heat of a burner flame and that emitted from surrounding red-hot combustion chamber walls.

For more critical applications than those described, the preferred instrument is the alternating-current radiometer, so called because a-c signals are developed by mechanically interrupting the light beam. Two important objectives are met by chopping the light before it strikes the detector; more efficient electronic amplifiers can be used, and the calibration accuracy is made independent of the detector sensitivity.

Despite high cost, a-c radiometer use is expanding. An 8"-diameter set with a thermistor detector can distinguish temperature differences of 0.01°C (based on a 25°C black body) with a response time of 0.1 second. Many applications arise in industry and research where no other type of thermometer will serve. Inaccessible objects and celestial readings are some examples. As early as 1885, the moon was examined by a primitive radiometer. Temperature distribution over the face of the planet Mars were shown in 1927 to vary from 30°C to −60°C.

Meteorology

An important mission for the Vanguard rocket was to carry two small radiometers back-to-back within the 20" satellite. Scanning across the world as the satellite rotated, the radiometers painted a crude pattern of the weather because clouds reflect more sunlight than the earth itself.

Meteorologists have long speculated on whether there was a correlation between weather cycles and thermal balance of the upper atmosphere. Other satellite configurations will be able to measure total radiation flux in and out of the atmosphere. More sophisticated weather satellites will probe the stratosphere to learn about temperature contours and air flows at high altitudes.

There are only certain characteristic wavelengths at which a gas can radiate. By filtering out all the other wavelengths, a radiometer can be made to respond to the emission of one particular gas of interest. Ozone radiates much as a black body at 9.6 microns. An orbiting radiometer, response limited to 9.6 microns, looking down to the earth, could determine the temperature of the ozone layer at 25 kilometers altitude.

Similarly a radiometer filtered for response at seven microns would sense the emission from the atmospheric water. Water radiates so strongly at seven microns that the satellite radiometer "sees" no more than the uppermost water molecules; thus, the temperature at about eleven kilometers altitude can be determined.

The practice of filtering radiometers to react to specific wavelengths opens a wide area of use.

Some 90% of the dollar volume today in infrared products is for military contracts. The earliest military usage was for communication. Now systems boasting a range of 10,000 yards in clear weather are commonplace in the U.S. Navy. Other smaller, battlefield units serve the Army Signal Corps.

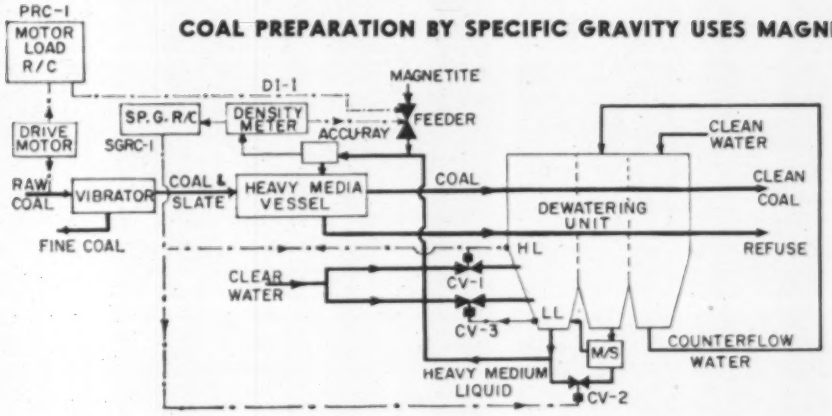
The Sidewinder air-to-air infrared-guided missile has been fully operational in the U.S. Navy for several years. Another infrared missile called the "Redeye" has been developed recently for ground troups in defense of low flying aircraft. Several jet interceptors, such as the F-104, use infrared gun sights.

At the Atlantic Missile Range, infrared trackers augment radar for following missiles during their boost phase. Accuracy of a typical compact unit is better than one minute of arc.

Satellites have been stabilized in orbit by downward-looking infrared horizon detectors, and infrared is sure to be indispensable for space navigation and guidance.

Process Control Systems

FRED D. MARTON, Instruments Publishing Company



COAL PREPARATION BY SPECIFIC GRAVITY USES MAGNETITE SUSPENSION

An automatic control system which recovers low-ash coal previously lost as waste, and prepares coal that is uniform in ash content, has been operating successfully at Underkoffler Coal Service Co., Lykens, Penna.

Pre-wet coal is conveyed to a vibrator, from which the raw coal is chuted to a heavy-media vessel to which a mixture of water and magnetite, a finely powdered ore, is piped as the separating medium. Specific gravity of this medium is controlled at 1.70. While the coal floats across the vessel, slate, rock, and other heavy material settle at the bottom where an oscillating rake lifts it to a discharge level. Both coal and refuse are chuted to a partitioned vibrator where water sprays drain off the medium for recirculation. A magnetic separator (M/S) further recovers magnetite.

Instrumentation is interlocked to a series of valves and mechanical devices to control specific gravity within $\pm 0.2\%$ of the optimum pre-set value of the medium and to add magnetite to the medium automatically, as needed.

A gamma-radiation unit measures the specific gravity to within ± 0.001 before the separatory medium (heavy medium solution) enters the heavy-media vessel.

Basic control is density of the heavy medium in the heavy-media vessel, which separates the coal from the heavier slate. This is done by an AccuRay unit, employing cesium 137, which measures the specific gravity of medium piped to the heavy-media vessel.

A signal from the density gage (DI-1) is amplified and transmitted through a density indicator to an ElectroniK recorder-controller with Electr-O-Volt proportional control units (SGRC-1). This unit controls motorized valves CV-1 and CV-2. The former (normally closed) opens on high density to admit clean water to the system, but is shut down if the level in the dewatering unit becomes too high (via *high-level* detector —HL). A low-level detector (LL) likewise operates water valve CV-3.

Valve CV-2 (motorized) opens on a high-level signal from HL, or on a low-density signal from the specific-gravity recorder controller (SGRC-1). When open, it bypasses heavy medium directly into the magnetic separator (M/S), which reduces the density and feeds the stream back into the dewatering unit.

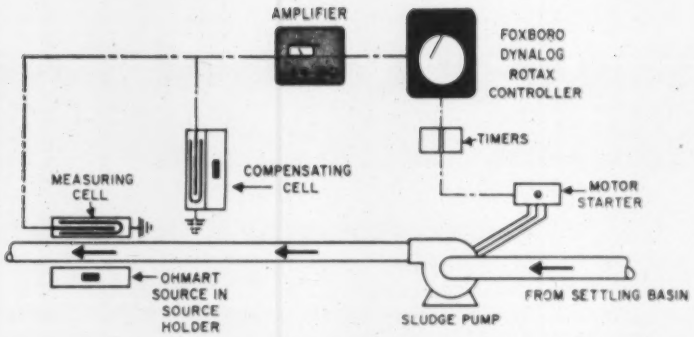
A second recorder-controller (PRC-1) measures current drawn by the motor driving the coal feed to the heavy-media vessel, and shuts down the magnetite feeder if coal flow falls below the prescribed minimum.

Recovery of magnetite solution is accomplished in three steps. Fast draining medium is sluiced directly to the main medium sump and returned to the vessel by pumping without further treatment. Medium still adhering to the coal and refuse is spray-washed into a washing hopper as the material moves along a vibrating screen and then pumped to a magnetic separator. Any magnetite still remaining on the coal is spray-washed into a counterflow hopper and the diluted solution recirculated through sprays over the washings sump and thence pumped to the magnetic separator. The magnetite is collected and concentrated, passed through a demagnetizing coil, and returns to the main medium sump for recirculation. Magnetite recovery is so thorough that it is necessary to add only 0.4 pounds of magnetite or less per ton of raw coal processed.

Main instrumentation used: Density detector (DI-1), AccuRay Model D-H2 (Industrial Nucleonics), with primary element; Minneapolis-Honeywell ElectroniK recorder, Model Y(14)2R13-VH-135-(W6)-11-(K2), with Electr-O-Volt controller (SGRC-1) incorporating a saturable reactor, which provides proportional-plus-rest control; two motorized valves: one in magnetite by-pass line (CV-1); the other one in the water line (CV-2); Minneapolis-Honeywell Modutrol motor; and load-recording ammeter (PRC-1) (Minneapolis-Honeywell Model Y202C1-(11)-23-III-74).

Source: Minneapolis-Honeywell Regulator Co., Industrial Div., Phila., Pa., and Industrial Nucleonics Corp., Columbus, Ohio.

POSITIVE DENSITY CONTROL SYSTEM FOR SLUDGE PUMPING



In the control of sludge pumping in sewage treatment plants one of the most important objectives is sludge of a consistent density.

This installation for controlling the density of the sludge uses a radiation-type density-control plus two timers.

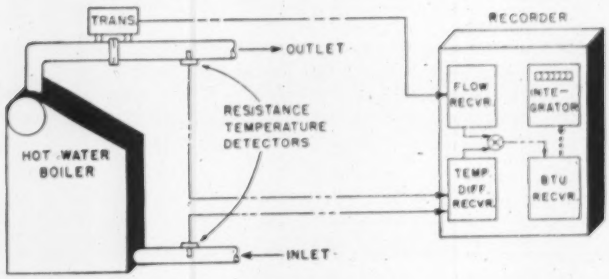
When the sludge density drops below a predetermined set point the controller shuts off the sludge pump and starts Timer No. 1. This adjustable timer keeps the pump shut off, allowing time for the sludge to build up in the hopper. A second time-delay timer then takes over, maintaining the sludge pump in the "on" position despite the density of the sludge being pumped, insuring that a new supply of raw sludge is being pumped into the metering section, and that the pump is not being controlled by residual sludge from the previous cycle.

In the primary element of the density meter, gamma rays penetrate a special transistion pipe section (and the material inside) to the measuring cell on the other side. As the solids content of the raw sludge changes, the amount of gamma rays reaching the measuring cell also varies. The gamma rays ionize the argon gas in the measuring cell, resulting in the generation of an electric current which flows in a shielded circuit. The amount of current flowing in this circuit is a function of the density of the sludge in the pipe section. The controller incorporates an electric multi-contacting unit. The pen of the controller, moving up or down scale rotates the shaft on which are mounted silver contacts which open and close the circuits activating tl : sludge pump.

Main equipment used: (1) Ohmart Density Control Cell; (2) Foxboro Dynalog Rotax Controller; (3) Amplifier.

Source: Ohmart Corp., Cincinnati, Ohio; also Ohmart Bulletin SD1; also Foxboro Company, Foxboro, Mass.

HEAT TRANSFER CONTROL BY BTU LOSS OR GAIN



Heat transfer in hot-water generators, cooling towers, refrigerating units, etc. in power and process industries is of great importance to the over-all efficiency of such systems. The balance of BTU's between inlet and outlet of a heat exchanger provides a good means of checking its proper functioning.

The measuring system uses a multiple-pen receiver-recorder which graphically registers) on a linear chart) liquid flow, differential temperature and BTU's plus integrated BTU's. Flow is measured by a suitable flow transmitter; resistance temperature elements sense the temperatures at inlet and outlet. The BTU receiver in the recorder receives the differential-temperature signal from a retransmitting slidewire in the temperature receiver. This signal is multiplied by a signal from the flow retransmitting slidewire. The product (times the specific heat factor of the liquid) can be read as the number of BTU's gained or lost per unit of time by the liquid as it passes through the process.

Equipment used: (1) Potentiometer Recorder, Model 771, 12″ circular chart with integrator readout. (2) Differential-Pressure Transmitter, Model 245, with electric signal output. (3) Two platinum resistance temperature elements with differential connection.

Source: The Hays Corp., Michigan City, Ind.; also General Catalog Section 59-B 913.

FIG. 1. GENERAL VIEW of Metrology Laboratory. CSIP long length measuring machine in foreground (only one in U. S.), measures 160 inches to ± 185 microinch accuracy.

THE METROLOGY STANDARDS LAB

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AVCO Research & Advanced Development
Wilmington, Mass.

TABLE 1—PHYSICAL MEASUREMENTS, ACCURACY CAPABILITIES, INCLUDING METROLOGY, HARDNESS, VIBRATION

VARIABLE	RANGE	ACCURACY	STANDARD
Length			
Gage Blocks	0.01 - 4.0 in	5 μin	Certified Gage Blocks & Comparator
	5.0 - 20.0 in	1 μin per inch of length	Certified Gage Blocks & Comparator
Linear	20 - 160 in	±(25 μin + 1 μin per inch length)	Gage Blocks & Long Length Meas. Machine
Angular			
Full Circle	0° - 360°	±3 seconds arc	Calibrated 30° Polygon
Small Angles	to 10 minutes	±0.2 seconds arc	Auto-collimator
Flatness			
Gage Blocks	All Sizes	±2 μin	Monochromatic Light with Optical Flats
Optical Surface	to 8-in diameter	±2 μin	Monochromatic Light with Optical Flats
Surface Plates	All Sizes	±25 μin	Auto-collimator
Surface Finish			
RMS	0 - 1000 μin	±10%	Profilometer
CLA	0 - 200 μin	±10%	Talysurf
Hardness			
Micro & Macro Knoop & Vickers	Full Range	Impression Length ±0.001mm	Certified Test Blocks
Rockwell	B&C Scale	±1.5 scale numbers	Certified Test Blocks
Screw Thread			
Lead	to 8 in O.D. (2)	20 μin	Lead Measuring Machine & Length Standard
Pitch Diam	to 12 in O.D. (2)	25 μin	Certified Set of Thread Wires
(2) all threads - internal, external, straight and tapered.			
Vibration			
Amplitude	0.001 - 0.4 inch (20 - 2000 cps)	±(1% + .001") to 0.1 in	Microscope with calibrated reticle
Acceleration	to 25 g's max	±4% to 10 g's	Calibrated Velocity pickup
Frequency	20 - 2000 cps	±0.2%	Freq. Standard & Comparison Oscilloscope
Sound	20 - 150 dbm (20 - 20k cps)	±0.2 db	Standard Microphone - Pressure Calib.

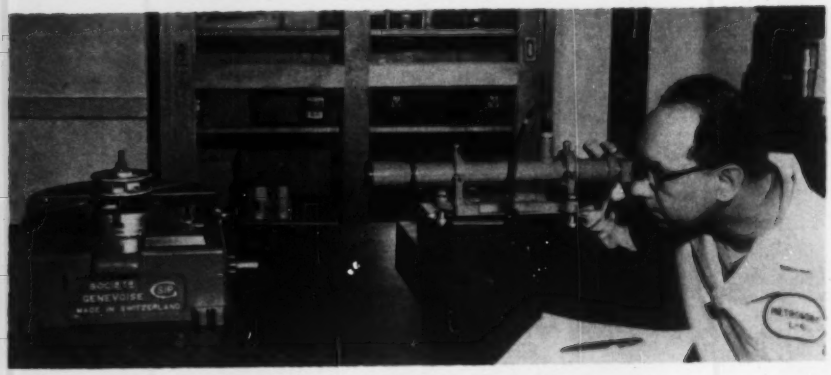

FIG. 2. CALIBRATION of optical dividing table.

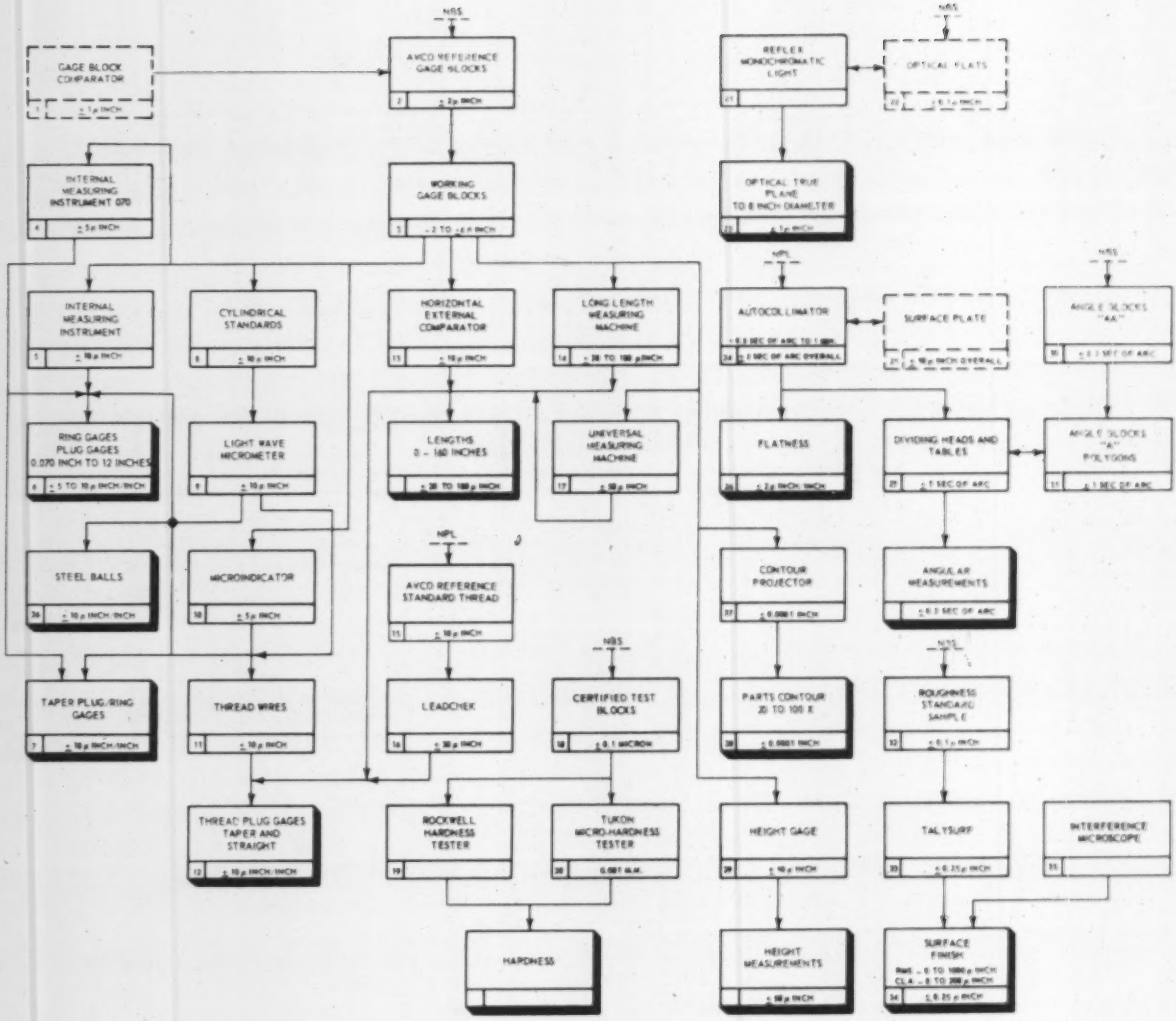

FIG. 3. MECHANICAL MEASUREMENTS flow-chart, showing test setups. Numbers in lower left corners of each block refer to the M numbers in table 3, which gives equipment and its uses. (A zero number implies general use.) Accuracy capability also is shown at each block.

TABLE 2—CODE OF MANUFACTURERS

ALD—Allison Labs, Inc., La Puenta, Calif.
AMO—American Time Products, Inc., New York, N. Y.
AVB—AVCO, R. A. D., Wilmington, Mass.
BAP—Bausch & Lomb, Rochester, N. Y.
BRK—Bruel & Kjaer, Cleveland, Ohio
BRQ—Brown & Sharpe, Providence, R. I.
CEH—Cenco Lerner, Cambridge, Mass.
CO9—Coventry Tool & Gage Co., Coventry, England
DOD—Do-All Co., Desplaines, Ill.
DUA—Dumont, Allen B., Clifton, N. J.
EAB—Eastman Kodak, Rochester, N. Y.
ECB—Eckel Corp., Cambridge, Mass.
ENB—Endevco Corp., Pasadena, Calif.
FOD—Fonda Gage, Inc., Stamford, Conn.
GAA—Gaertner Scientific, Chicago, Illinois
GEB—General Radio Co., W. Concord, Mass.
HEA—Hewlett Packard Co., Palo Alto, Calif.
HID—Hilger & Watts, London, England
HUC—Hunter Mfg., Co., Inc., Iowa City, Iowa
LEA—Leeds & Northrup, Philadelphia, Penna.
LEC—Leitz Co., Ernest, New York, N. Y.
MBA—M. B. Mfg. Co., New Haven, Conn.
MIS—Micrometrical Development, Ann Arbor, Mich.
PRG—Pratt & Whitney, West Hartford, Conn.
SHC—Sheffield Corp., Dayton, Ohio
SOH—Societe Genovese, Geneva, Switzerland
SWB—Swedish Gage Co., Cleveland
TAD—Taylor-Hobson, Leichester, England
VAF—Van Keuren, Watertown, Mass.
WAR—Watts Regulator Co., Lawrence, Mass.
WED—Western Electric, Los Angeles, Calif.
WFI—Webber Gage Co., Cleveland, Ohio
WEK—Webber Laboratory, Cleveland, Ohio
WEO—Western Electric Acoustic Labs., Los Angeles, Calif.
WIG—Wilson Mechanical, New York, N. Y.
ZEA—Zeiss Carl, New York, N. Y.

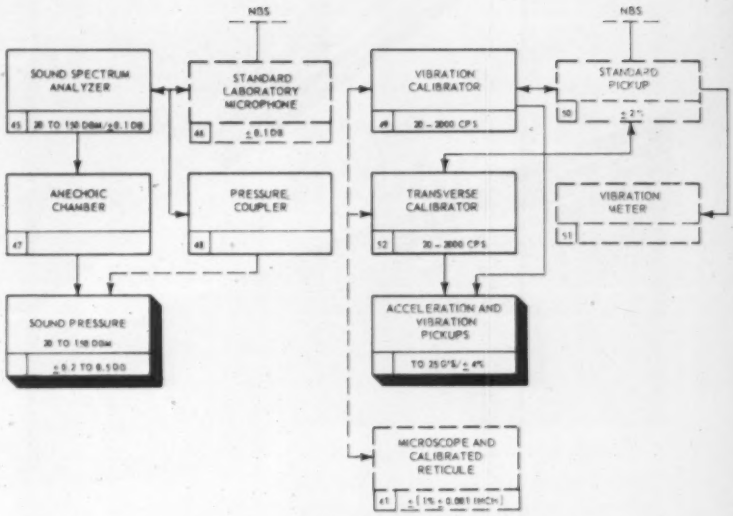

FIG. 4. ELECTROMECHANICAL MEASUREMENTS flow chart for audio, acceleration and vibration calibrators. Numbers in corner refer to EM numbers in Table 3. Accuracy capability also is shown.

TABLE 3—METROLOGY INSTRUMENTATION LIST

ITEM	MANUFACTURER and MODEL	APPLICATION
Accelerometer	ENB 2213	EM0
Amplifier	ENB 2614, 2616	EM52
Analyzer, Harmonic Wave	GEB 736A	
Analyzer, Sound Spectrum	WEO 1000E	EM45
Auto Collimator	HID TA-1	M24
Balls, Precision	VAF	M36
Blocks, Angle	WEK AA	M30
Blocks, Angle Laboratory	WEK 16A	M31, 27
Blocks, Gage	DOD AA	M2
Blocks, Gage	SWB	M3
Blocks, Gage	FOD 84, 103	M3
Blocks, Hoke	PRG 88	M2
Blocks, Hoke Long	PRG 8	M3
Calibrator, Accelerometer Transverse Sensitivity	ENB Special	EM52
Calibrator, Vibration Pickup	MBA C11	EM49
Cathetometer	GAA	M0, EM0
Cathode Follower	ENB 2608	EM52
Chamber, Acoustical	ECB AN-ECK-OIC	EM47
Comparator, Gage Block	SHC	M1
Comparator, Horizontal Ext.	SHC 51EHC	M13
Comparator, Millionth	PRG B-4	M1
Counter, Electronic	HEA 522B	EM49
Cylinders, Standard	VAF	M8
Exciter, Vibration	MBA C11	EM49
Galvanometer, Reflecting	RUA 3202	EM0
Generator, BF Oscillator	BRK 1014	EM47, 48
Generator, Oscillator	HEA 200CD	EM49
Indicator, Force	HUC LO-1M, LO-5-M	M0
Indicator, Height	SHC	M29
Int. Measuring Instrument	SHC 070	M4
Int. Measuring Instrument	SHC N7	M5
Lab Jacks	CEH 19086, 19089	EM0, M0
Lead Measuring Instrument	SHC TS8	M16
Light, Monochromatic	VAF Reflex	M21
Meter, Vibration	MBA M-3	EM49
Microindicator	SOH MI-6B	M10
Micrometer, Light Wave	VAF 3 inch	M9
Micrometer Check Set	DOD	M0
Microphone, Condenser	WED 640AA	EM46
Microphone, Laboratory	ALD 21BR150	EM0
Microscope	BAP YD 7313	EM41
Microscope	LEC	EM0
Microscope	BAP OC-2	EM41
Microscope	AMO 376649	M0
Microscope, Interference	ZEA	M35
Mirror, Target	WEE	M0
Optical Flats	DOD X95, 1" + 2"	M22
Optical Flats	VAF 2", 3", 6", 8"	M22
Oscilloscope	DUA 304-AR	EM49
Oscilloscope	DUA 350-R	EM49
Oscilloscope	HEA 130A	E0, EM0
Parallels, Granite	BRQ 6", 12", 18"	M0, M27
Pickup, Probe	MBA 115	EM50
Plate, Angle Granite	BRQ	M0, M27
Plate, Surface Steel		M0
Polygon, 30°	WAR	M31
Power Supply	ENB 2622	EM49
Power Supply, Microphone	ALD 526B	EM0
Projector, Contour	EAB 30	M28
Profilometer	MIS 8	M0
Ratio Box	MBA R2	EM49
Spectrometer, Audio	BRK 2311	EM45, 48
Square, True	WEE AICO1	M0
Surface Plate, Granite	DOD 48" x 72"	M25
Surface Finish Instrument	TAD Talysurf 3	M33
Table, Rotary Optical	SHC	
Table, Rotary Optical	SOH	M27
Tester, Rockwell	WIG 3JR	M19
Tester, Tukon Hardness	WIG LR	M20
Thermocouple	LEA 8710	EM29
Thread, Standard	CO9	M15
Universal Measuring Machine	SOH MU-214B	M17
Universal Measuring Machine	SOH MUL-4000	M14
Vibration Pickup	AVB	EM0, M0
Wires, Thread Measuring	VAF	M11

Note: Mention of company does not imply endorsement. Other firms offer similar equipments. The purchaser should compare all sources for latest equipments.

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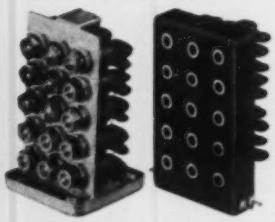

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Hathaway INSTRUMENTS, INC.

CIRCLE 80 ON READER-SERVICE CARD

Automatic Flowmeter Calibration

H. A. LENT, General Electric Company, Instrument Dept., West Lynn

AUTOMATIC flowmeter calibration can result in (1) lower costs, (2) more accurate data, (3) more consistent test results, and (4) less clerical work.

Principles of Operation

Two flowmeter transmitters are connected in series in the flowstand in a manner similar to that shown in Fig. 1. That is, the same fluid stream passes through both of succession. The flow rate indicated by each one should be the same, if the transmitters have identical output characteristics. Then, if one output is subtracted from the other (by bucking their respective voltages), a relative error of zero voltage difference would be measured at each scale point (flow rate).

The master transmitter is a standard, which has been calibrated against primary flow standards. Hence the scale error of its ouput signal (with respect to an ideal transmitter) is known at each flow-rate calibration point. The second (test) transmitter errors are unkown and are to be determined. If the outputs are subtracted electrically, there will result a series of numbers which would represent the errors in both instruments (compared to an ideal instrument) at each flow point.

Corrections are introduced into the electrical output of the standard to compensate for the known error at each scale point. The resulting numbers obtained by subtraction of the outputs of the two transmitters represent errors in the characteristic of the test transmitter alone. This is the basis of the flowmeter error-recording system.

Operation

The master transmitter supplies an electrical

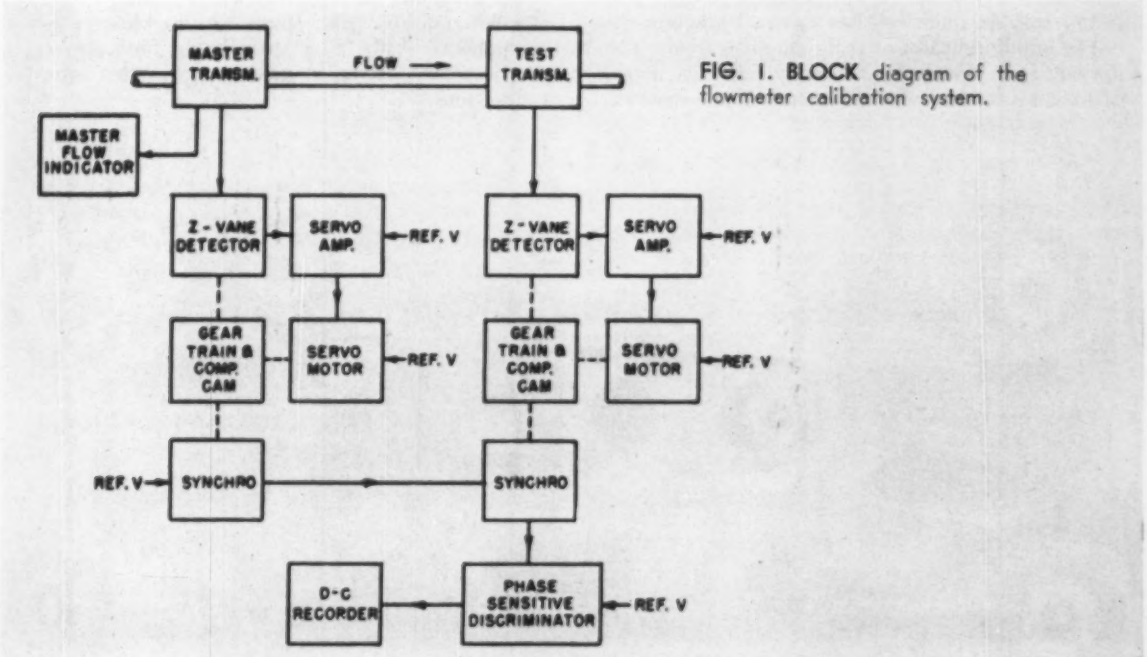


FIG. 1. BLOCK diagram of the flowmeter calibration system.

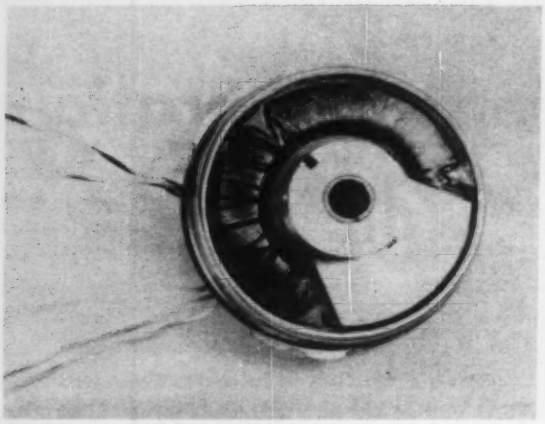


FIG. 2. Z-VANE detector.

signal to a master flow indicator as well as to the detector element of the "standard" servo loop (left in Fig. 1). It is by means of his standard indicator that the fluid flow rate is accurately set and monitored. The standard flow indicator is a precision 800-cycle self-synchronous repeater with an angular accuracy and readability of 0.1 degree.

The Z-vane detector (Fig. 2) is an assembly which acts as a receiver of signals from an 800-cycle 2nd-harmonic-type transmitter element. The assembly consists of a toroidally-wound tapped coil whose four leads are connected back-to-back to the transmitter coil. An inner coil has its two leads brought out to a null indicator or servo-amplifier input. The Z-vane, from which the assembly takes its name, is a rotor assembly which is mounted on a shaft extending through the two coils. Two sector-shaped pieces of magnetic material are mounted on either end of the shaft and positioned at 180° from each other. These vanes magnetically link the inner and outer coils, and the vane assembly can be rotated to produce a null voltage output from the inner coil for each position of the transmitter.

The standard servo loop takes the electrical signal and accurately positions the shaft of a synchro control transformer to an angular position corresponding to the position of the master flow transmitter. The test servo loop (right in Fig. 1) is similar to the standard loop and its function is to likewise position a synchro shaft to an angular position corresponding to that of the test transmitter.

In Fig. 1 the left-hand synchro is a control transmitter and the right-hand synchro is a control transformer. With the left-hand synchro rotor excited by the 26-volt 400-cycle reference voltage and the stator windings of the CX and CT interconnected, any change in the relative positions of the rotor of these two synchros will result in the generation of a voltage signal in the rotor of the CT. This signal is fed into the phase-sensitive discriminator as the error-voltage to be recorded.

The relative angular positions of these synchro rotors have been preset so that for identical angular positions of the flowmeter turbine the synchro rotors are 90 electrical degrees apart. Thus, if the electrical outputs of the flow transmitters are identical (a condition representing a zero error signal), the signal output of the synchro pair will be essentially linear and will have a positive or negative polarity depending upon the algebraic sign of the relative error between the flowmeter transmitters.

The signal output of the synchro pair is fed into a phase-sensitive discriminator where it is rectified, then measured on a recording d-c microammeter with a zero-center chart.

The elements of the flowmeter recording system are shown in Fig. 3. The control cabinet houses the components of the two servo loops and supplies the necessary power, switching and system interconnections.

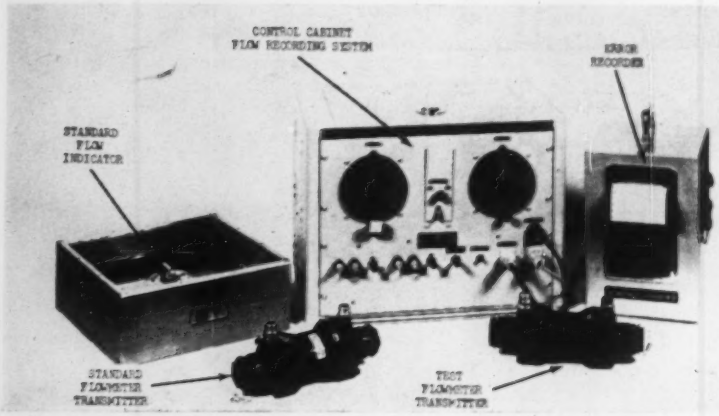


FIG. 3. ELEMENTS of the recording system.

FIRST* DC Standards Laboratory

PRIMARY-STANDARD
DC VOLTAGE DIVIDER

0.0001 %
ABSOLUTE

PRIMARY-STANDARD
ABSOLUTE DC VOLTAGE REFERENCE

0.0001 %
ABSOLUTE

PRIMARY-STANDARD
DC VOLTAGE-CURRENT POTENTIOMETER

VOLTAGE
0.0015 % ABS.
CURRENT
0.003 % ABS.

ULTRA-PRECISE
DC VOLTAGE GENERATOR-CALIBRATOR

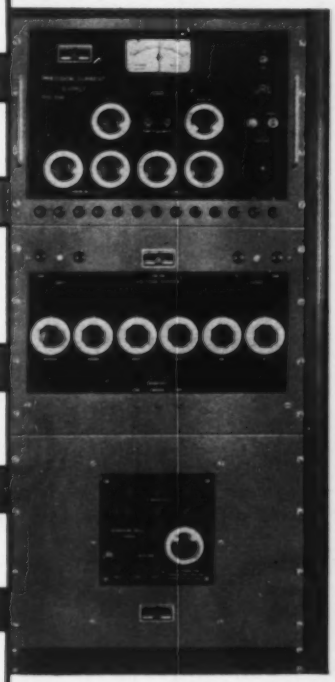
0.0015 %
ABSOLUTE

ULTRA-PRECISE
DC CURRENT GENERATOR-CALIBRATOR

0.003 %
ABSOLUTE

ULTRA-SENSITIVE
DC AMPLIFIER-NULL DETECTOR

2μV
THRESHOLD



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CIRCLE 81 ON READER-SERVICE CARD

The Dynamic Storage Analog

Dynamic storage, or memory, opens new fields for analog computation and simulation, including sequential calculations, definite integrals and multiple integrations.

RECENT developments in precision analog computers have increased their versatility and speed. Probably the two most important are (1) *automatic repetitive operation* at frequencies of 60 cps, and (2) *high-speed memory* with a tracking error of less than 0.5 microsecond.

The digital computer employs a memory so that a large complex problem can be solved by time sharing the digital-computer equipment and using the same equipment repeatedly to solve sections of the problem. Thus, large problems require longer solution times rather than larger computers (as was previously true for analog computers).

For many types of problems, the disadvantage of larger sizes in the analog computer has been overcome by the development of high-speed memory which is employed (as in the digital computer) for time sharing to increase the time of solution rather than increasing the size of the computer for complex problems. Solution times still remain relatively short compared to those required for digital solution of the same problems.

Uses of Repetitive Operation

Distillation problems in the process industry have tested the computing capabilities of both analog and digital machines. Prior to the development of high-speed repetitive operations and dynamic-storage analog computers, a 4-component distillation problem with overhead, sidestream, and bottoms products would require more than 1000 analog-computer amplifiers for the simultaneous solution of a 30-plate column, or, conversely, a solution time of several hours (on a *digital computer*). With a modern DYSTAC Analog Computer in repetitive operation, such a solution can be obtained with only 43 amplifiers in approximately 1 minute of operating time. This compares favorably with the more expensive digital computers.

Memory also can be employed with high-speed sequential calculations as follows: (1) To obtain definite integrals for automated, self-solution of various problems; probably the most common example is economic optimization of an operating process. (2) A combination of repetitive and non-repetitive operations can provide a simple, accurate, and rapid solution for multiple integration; solutions for various types of transient operations and difference-differential equations of the most complex problems is about 20 seconds. (3) An all-electronic transport delay can be derived from standard computer components. (4) Differentiation can be performed without the noise heretofore associated with it.

Dynamic Memory

Fig. 1 shows a conventional integrator. The high-gain amplifier with feedback capacitor (C) and input resistor (R_1) constitute a standard non-repetitive operating integrator. Relays A and B reset the integrator to the applied initial-condition voltage; during the reset period relay A is open and relay B is closed. During this period, the capacitor is biased to produce an output of E_o, which is the negative value of the initial condition imposed on the initial-condition resistor network. That is, E_o is the inverse of the I.C. signal. When the operate cycle is initiated, relay B is opened and relay A closed, so that the voltage input E_1 can be integrated. The time-integrated value of E_1 starting from the appropriate initial condition is then the output voltage E_o.

Fig. 2 shows the output voltage E_o during the operate and reset cycles for a decaying function $F(x)$.

At the beginning of the operate cycle, the value of E_o is the initial condition. During the subsequent integration the value of E_o follows the time integral of x, which corresponds to $F(x)$. At the termination of the operate cycle, the computer is returned to the reset period, where the value of E_o is again changed to correspond to the initial condition.

If a second integrator, acting as a memory, is in reset (relay B closed) and has no input other than $F(x)$ through the initial-condition channel (Fig. 3), it will track $F(x)$ and have for an output

Presented at Western Joint Computer Conference, San Francisco, May, 1960

Computer--DYSTAC

JACK M. ANDREWS, Computer Systems, Inc.

voltage the value $-F(x)$. If the B relay is caused to open at any given value (x_1) of the variable x, then the output will subsequently remain constant at $F_1(x)$ for all values of x greater than x_1. During the reset period, if the B relay of the second integrator is again closed, the memory will track $F(x)$ while the integrator is resetting.

In this manner, by using the initial-condition input, memory can be incorporated into a standard integrator. It will be shown that practical applications of this technique require repetitive operation at frequencies of from 1 to 200 cps, preferably 50 cps or greater. This procedure in repetitive operation is possible only when the reset relay B is replaced by an electronic switch which operates at a speed of approximately 5 microseconds, and resets the amplifier independent of the RC time-constant of the initial-condition circuit.

Types of Memory Circuit

Four types of memory are ordinarily employed. Shorthand symbols for these memory circuits are shown in Fig. 4.

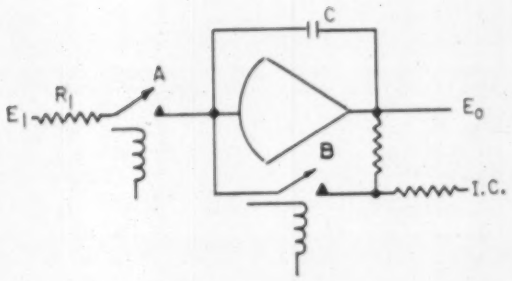

FIG. 1. CONVENTIONAL INTEGRATOR for non-repetitive use.

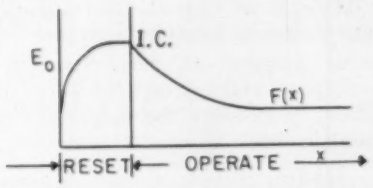

FIG. 2. OUTPUT of amplifier which is first reset to an initial condition and then integrates a decaying function.

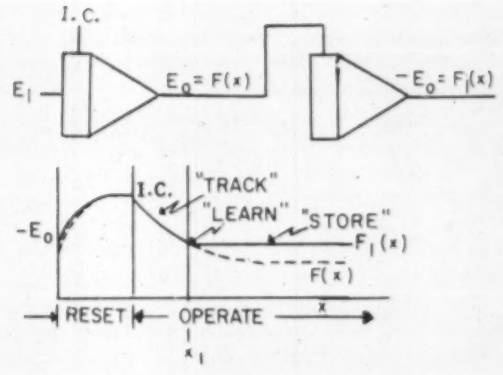

FIG. 3. SECOND AMPLIFIER, which receives F(x) signal at its I.C. input, tracks and inverts the signal. The second amplifier can be "stopped" at a predetermined value of x to provide memory.

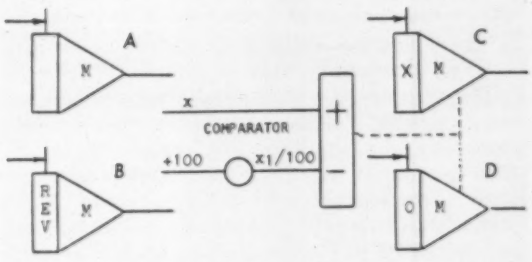

FIG. 4. DYSTAC memory symbols. A is standard integrator or forward memory. B is a reverse memory. Both have their reset switches controlled by pulses from the computer. C and D are amplifiers whose reset switch is normally closed until reset; in D the switch is normally open.

The letter M indicates that the amplifier is being used as a memory, and is a reminder that the normal input channels to the amplifier should not be used; the only input is through the initial-condition channel. The standard integrator (Fig. 4A), termed a forward memory, "tracks" the function during the computer reset period and commences to "store" or hold the signal during the computer operate period until it is commanded to store or hold the signal.

Fig. 4B shows a *reverse memory*. In this application the polarity of the control signal is reversed so that the electronic reset switch operation is reversed. Hence the output voltage tracks its input voltage during the operate period; during the reset period the output voltage is stored (at the value last available through the initial-condition input at the termination of the operate cycle). Both memories are controlled by repetitive automatic-reset pulses generated by the computer.

In Fig. 4C and D the electronic reset switches are actuated by external voltage comparators rather than by the repetitive, automatic reset pulses. Fig. 4C shows an amplifier whose electronic switch is normally closed until the external comparator is actuated by an independent or dependent variable whose value exceeds that of an arbitrary voltage (x_1). This is called X memory. The output voltage tracks the value available at the initial-condition input until the comparator is actuated, at which time the output voltage is locked or stored at the instantaneous initial-condition value.

Fig. 4D shows an integrator memory whose reset electronic switch is normally open until the comparator is actuated (O-memory). The output voltage is stored and constant until the comparator is actuated. At this time the output voltage tracks the initial-condition input.

Sequential Calculations

To perform high-speed sequential operations which are automatically controlled by the computer, it is necessary to have an *accounting circuit* which records the number of steps that have been performed and whose output voltage is synchronous with the computer operate cycles and can serve as an indication for relay amplifiers and comparative circuits through which the type and complexity of the sequential calculations can be regulated. Such an accounting circuit is presented in Fig. 5.

This circuitry is composed of a reverse and forward memory together with an inverter summer, relay, and relay amplifier. If it is assumed that M_x (the number of sequential calculations to be performed, represented in volts) has a value of 30, and Δ has a value of 1, a constant value of one volt will be added to P_N through the summer for each computer cycle.

The relay amplifier will compare $+P_N$ with a value of 30 and operate the relay, driving it from the normally closed (X) to the normally open (O) position when P_N has attained 30 volts.

Let us assume that P_N has reached a value of 30 volts. This value will be maintained at the output of the forward memory during the remainder of the current operate cycle; hence the forward memory will be in "store." With the arm of the relay at the normally open position, a ground will be imposed through the initial-condition channel of the reverse memory, which will track this value and hold it at the end of the current operate cycle. During the next reset period the reverse memory will store the output value of zero, and the forward memory will track and learn it since its electronic switch is closed during the reset cycle. In the next operating cycle the forward memory will have learned and stored a value of zero (which will appear as its output). During this cycle, when P_N has a value of zero, the relay will return to its normally closed position and the value of P_N plus one volt will appear at the initial-condition input of the reverse memory. Therefore, during the next operate cycle the value P_{N+1} appearing at the output of the reverse memory will be one volt. This value is in turn stored at the output during the reset cycle, and the forward memory will "learn" a value of 1 volt, which it will maintain during the following operate cycle. In this manner, P_N will have voltage values varying in incremental steps of 1 volt from 0 to the maximum value M_x.

During the corresponding cycle the value appearing as P_{N+1} at the output of the reverse memory will always be 1 volt greater until P_N is equal to the maximum voltage (M_x), at which time P_{N+1} will be zero. Either P_N or P_{N+1} can be used as control voltages to actuate either relay amplifiers or electronic switches to control the various sequential calculations which are incorporated in the cycle from $P_N = 0$ to $P_N = M_x$. The cycle thus effected by this control will be reiterative and will cycle through the various sequential calculations until the repetition is halted by the operator. This feature provides an efficient means for conducting sequential algebraic calculations such as are encountered in distillation, difference differential equations, partial differential equations, and in control problems where the control variables are cycled through a series of operating conditions or boundary conditions—all in synchronism with the computer.

The *ratchet circuit* (Fig. 6) is another type of memory circuit which finds its application in the memorization of values from one cycle to be used in the succeeding cycle.

The forward memory will produce a value of x_N which will be utilized throughout an entire cycle in the calculation of the value of x_{N+1} that is necessary for the following cycle. This value (x_{N+1}) is derived from the associated problem circuitry, and will be memorized during the reset period to provide x_{N+1} for the calculation of x_{N+2}, etc.

The multi-component distillation problem mentioned previously employs both ratchet and accounting circuits for time sharing of computer components. The solution is based on a trial and error procedure with a continuous solution frequency of 60 plates per second. A solution with an accuracy of 0.1% can be obtained for a given case in about 1

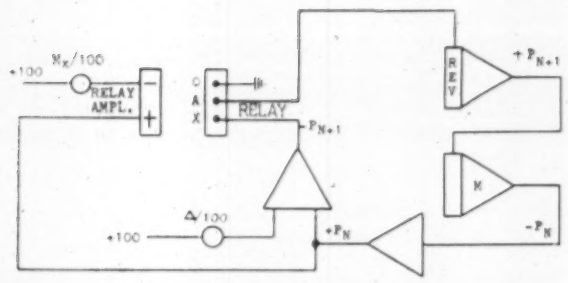

FIG. 5. ACCOUNTING CIRCUIT. Relay amplifier controls relay that operates memory unit.

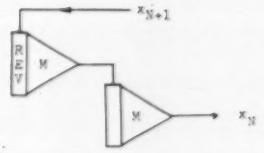

FIG. 6. RATCHET CIRCUIT is memory that uses values from one cycle in the next cycle.

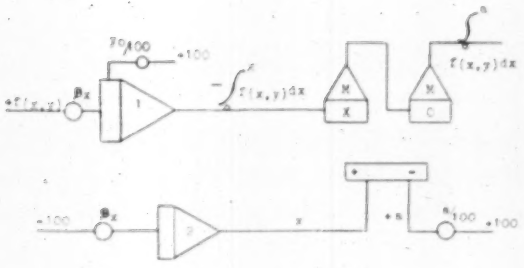

FIG. 7. EVALUATION of a definite integral by use of an X and O memory.

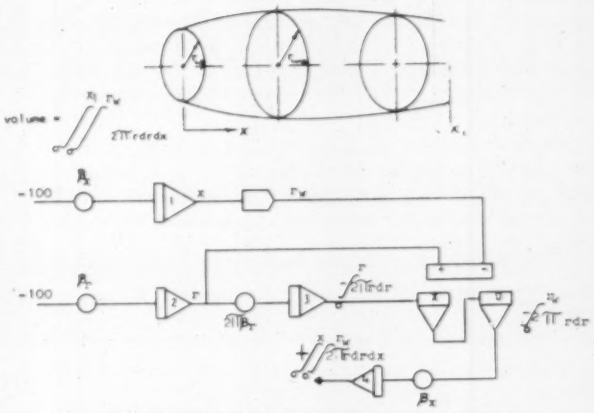

FIG. 8. MULTIPLE INTEGRATION. Volume of cylindrical shape is double integral with respect to (1) radius and (2) length.

minute after the basic data has been set in the computer. Only 43 operational amplifiers are required for a four-component distillation. This contrasts with a requirement in excess of 1000 amplifiers for conventional analog-computer equipment.

The Definite Integral

In many problems it is desired to evaluate the integral of various quantities, in repetitive operation, at definite and sometimes changing limit. Examples include economic optimization, the minimization of transients through design parameters in a control system, and the evaluation on a least-mean-squares basis of correlation coefficients.

The evaluation of a definite integral by use of X and O memories in repetitive operation is illustrated in Fig. 7.

It is desired to determine the definite integral of $f(x,y)$ with respect to the variable x. The desired function is the input to integrator 1, wherein the proper initial condition, y_o, is available. The output of integrator 1 is the *indefinite* integral with respect to x. In this application, integrator 1 will be operated in the repetitive mode. Integrator 2 will also be operated in the repetitive mode; its purpose is to generate a ramp function for the evaluation of the limit of the integral (with respect to x) of $f(x,y)$. x is compared with the value *a* from a reference voltage to establish the upper limit of the desired *definite* integral. *a* may be a constant or a function of y.

The x memory will track the indefinite integral—$\int_o^x f(x,y)dx$—as it is produced in repetitive operation mode until x is equal to a. At this point, the X memory locks and the O memory begins to track with the result that the O memory has as its output the previous evaluation of the definite integral from 0 to *a* from each preceding cycle. It is feasible to vary the limit of integration *a* from one cycle to another. In this case it would be provided by some other portion of the circuitry in accordance with the desired problem solution.

When it is desired to obtain the economic optimum operating conditions for a process it is generally necessary to evaluate definite integrations. A similar technique can be employed with repetitive operation evaluation of definite integrals and feedback loops from non-repetitive operation to evaluate the design variables which minimize the transients in an instrumentation problem. Still another example is the evaluation of the correlation coefficients which provide the best least-mean-squares fit of observed data.

Multiple Integration

In Fig. 8, it is desired to determine the volume of a cylinder with varying radius. This volume is the *double integration* with respect to radius (r) and length (x).

The radius is obtained from a diode function generator as a function of length. The radial (r) integrators operate in repetitive mode while the axial (x) integrators operate in non-repetitive

mode. The value of x is obtained from integrator 1 (non-repetitive) and fed to the DFG from which the instantaneous value of the radius at the wall (r_w) is obtained. r is obtained from the repetitive operating integrator 2 and is fed through a pot (set at $2\pi\beta r$) to repetitive integrator 3, which gives the cross-sectional area at any point in a cycle. The upper limit of this integration is fixed by the X and O memories. The X memory tracks until r is equal to the radius of the wall, at which point it locks. The O memory starts tracking when the comparator shows that the wall has been reached, and its output is always the previous value of the cross-sectional area at the wall. This, in turn, is directed to integrator 4 operating non-repetitively. The output of this last integrator is the volume of the cylinder at any axial location, x.

While this simple multiple integration used for illustration is relatively trivial, the same sequence is followed in developing temperature gradients in a fixed-bed chemical reactor operating under steady-state conditions.

The solution procedure outlined cannot be obtained from conventional analog computers because the known radial boundary conditions are split and the radial function R must be solved automatically by the computer in repetitive operations. In this particular problem, the value of R (a function of radius, r) is known at the wall while dR/dr is known at the center of the tube where the radius is zero. This solution is readily accomplished in repetitive operations with DYSTAC memories. The solution reduces a split-boundary value problem in R to an initial-condition problem.

Continuous Memory

Point memory and the ratchet circuits will solve many problems involving ordinary and partial differential equations. However, there is frequently a requirement for continuous memory of a varying dependent or independent function. Although there are several variations of the proposed continuous-memory circuit, a simple illustration (Fig. 9) demonstrates its potential applications.

The most common requirement of continuous memory is illustrated by the variation of f(x) with the solution curves 0,1,2, etc. The function Fl for f(x) is required as input to the computer circuit to predict F2. Solution F1 will be required for one full cycle of the repetitive operation, during which the values of F2 for the subsequent operating cycle will be produced. In the subsequent operating cycle the values from F2 will be required to calculate another curve, F3.

The memory circuit is based on Newton's Forward Interpolation Formula. This relationship states that if for equal increments of the dependent or independent variable x the values of f(x) are known, these values may be used to express f(x) as a function of x as shown in the polynomial equation in Fig. 9. The values of coefficients, A, B, C, and D for this equation are derived from the differences shown in the difference tabulation. Thus, if the values of $f(x_a)$, $f(x_b)$, $f(x_c)$, and $f(x_d)$

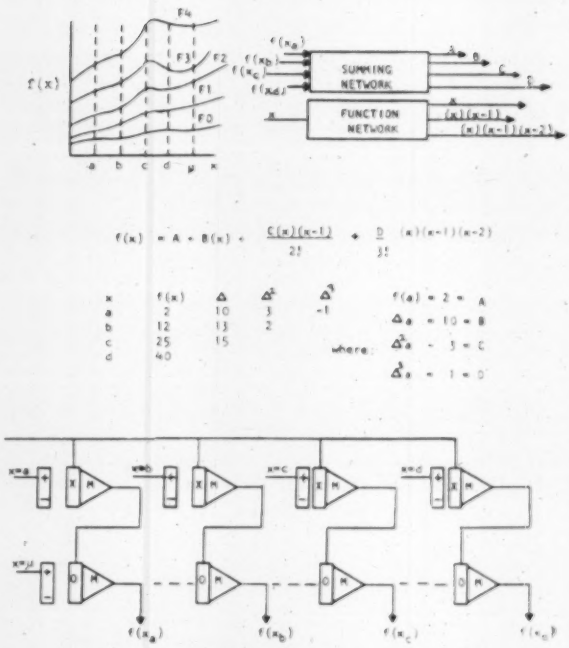

FIG. 9. CONTINUOUS memory circuit.

are known, they may be directed to a summing network from which the coefficients, A, B, C, and D can be derived. Simultaneously, the value of x can be sent to a function network which produces the required products of x, x—1, and x—2, that are necessary for Newton's Formula.

One simple scheme whereby the required values of f(x) for curve 1 may be retained in memory while new values for curve 2 are learned for the subsequent cycle is shown, using four pairs of X and O memories. During the first cycle the values of $f(x_a)$, $f(x_b)$, $f(x_c)$ and $f(x_d)$ for curve F0 are present at the outputs of the respective O memories; these values are then fed to the required summing network that produces the coefficients A, B, C, and D, which are used in the development of the curve F1 as x varies. At the same time the respective X memories have relay comparators which open the first memory when x is equal to a, the second memory when x is equal to b, the third memory when x is equal to c, and the fourth memory when x is equal to d. As the X memories are fed by the computer with the newly calculated curve F1, at the end of the cycle the values of $f(x_a)$, $f(x_b)$, $f(x_c)$, and $f(x_d)$ for curve F1 are locked in the respective X memories. It is necessary to translate these values into the O memories for the subsequent cycle, and this is done at the end of the current cycle. This is accomplished by one common comparator circuit that switches all four O memories when the value of x is equal to μ, which is a value greater than x_d.

The DYSTAC computer has provided rapid economic solutions to problems which have heretofore been so tedious or expensive to resolve that either gross approximations have been incorporated into the solution—or else the problem neglected.

Use of Analog Memory for Simulation of a Melting Slab

Here is how memory can be used in an analog computer to reduce computation time. Relays are used with a conventional analog computer to switch the integrators between hold and IC to provide M (forward) and R (reverse) memory. This permits the computer to solve the melting problem incrementally.

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MEASUREMENT of the temperature distribution in the interior of a melting solid is encountered in the study of materials. Most techniques suggested for analysis of the problem use the digital computer. However, the use of the analog computer permits one to obtain solutions more rapidly.

The Landau method, or similar mapping techniques for analog simulation, are inconvenient for two- or higher-dimensional systems; complication generally results from the use of mapping. An alternative approach to the melting problem consists of replacing the distributed system by a discrete system, and then allowing the solid to melt incrementally.

The incremental melting method also is directly applicable to the more sophisticated ablation problem and also the multidimensional case.[2]

The Problem

Consider an infinite slab of thickness 1 (Fig. 1) which is subjected to a heat flux uniformly distributed over one boundary, with the other boundary insulated. Due to the uniformity of the boundary conditions, the heat transfer need be considered only for a unit surface area. The heat flux (Q) will cause the temperature (T) in the interior to rise. The slab begins to melt when its surface reaches the melting temperature (T_M). It is assumed first that the melted portion of the material is swept away so that it has no effect on the subsequent heat-

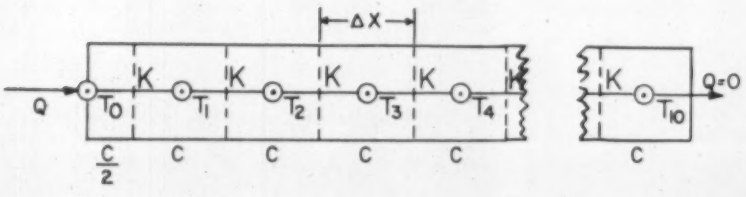

FIG. 1. SLAB (considered incrementally) for temperature T_o less than melting temperature T_M.

Terminology and Equations

$T(x,t)$ = Slab temperature at point x and time t, degrees F.

T_M = Melting temperature, degrees F.

x = Distance normal and interior to the slab from the conductive boundary, inches.

S = Location of melting surface, inches.

ρ = Slab density, lbs/in^3

C_v = Specific heat, Btu/lb-°F

k = Thermal conductivity, Btu/in-sec-°F

L = Latent heat of fusion, Btu/lb

q_o = External heat flow at melting surface per unit area, Btu/in^2-sec

Q = Total heat flow at melting surface = q_oA, Btu/sec

K = Total conductivity between "cell centers" = $kA/\Delta x$, Btu/sec-°F (6)

C = heat capacity of one "cell", Btu/°F = $\rho C_v A(\Delta x)$ (7)

$k(\partial^2T/\partial x^2)$ = Local accumulation of heat = $(\rho C_v)(\partial T/\partial t)$ (1)

$C(dT/dt) = \Sigma K(\Delta T)$. Heat stored equals heat in minus heat out. (3)

$k(\partial T/\partial x) = \rho L(dS/dt) - q_o$. Heat balance at melting surface: tells rate at which surface S advances (2)

transfer process, and second that the diffusivity of the slab is constant, which suppositions do not seriously alter the approach.

The equation expressing the temperature distribution in the interior of the slab is the conventional heat-flow equation:

$$k(\partial^2T/\partial x^2) = (\rho C_V)(\partial T/\partial t) \qquad (1)$$

with boundary conditions:

$T(x,0) = 0$. [Initial temperature is 0]

$T(S,t) = T_M$. [Temperature at melting surface (S) is T_M, at any time.]

Heat flow in at the melting surface must equal the heat absorbed by melting plus heat flow out to right. This heat-balance equation is:

$$k\partial T/\partial X(S,t) = \rho L(dS/dt) - q_o \qquad (2)$$

$\partial T/\partial x(1,t) = 0$. [No heat flow at right end (insulated)]

$dS/dt = 0$ when $T(0,t) < T_M$. [Melting starts when left end is at T_M.]

Method of Solution

The partial derivative with respect to the space variable, x, will be replaced by a standard finite

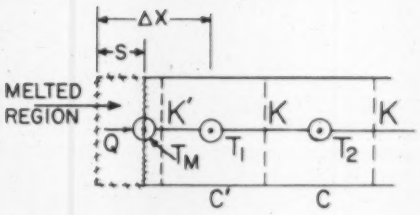

FIG. 2. SLAB after T_o equals T_M.

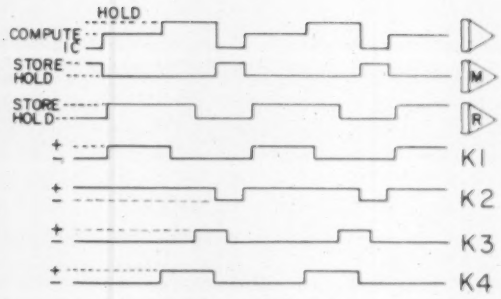

FIG. 3. FOUR RELAYS (K1, K2, K3, K4) control the computer elements to obtain M and R memory action.

difference. Since the finite difference representation depends on the location of cell centers, it will be time dependent on the motion of the melting surface. The use of this technique depends on the ability to determine the node spacing for the discrete system so that the incremental melting method will lead to an accurate representation of the internal temperature distribution of the body. There exists a criterion which permits such a specification of node spacing[1]. The spacing is initially chosen in accordance with this reference (1).

In the non-melted region, the differential equation is approximated by

$$C(dT_n/dt) = \text{Heat stored}$$

$$= \text{(Heat in from right) plus (heat in from left)}$$

$$= K(T_{n+1} - T_n) + K(T_{n-1} - T_n)$$

$$= K(T_{n+1} + T_{n-1} - 2T_n) \qquad (3)$$

The slab section is assumed to consist of ten identical cells in addition to a half cell at the conductive boundary (Fig. 1). Before T_o reaches the melting temperature (T_M), the non-insulated (left) boundary condition is given by:

$$Q = K(T_o - T_1) + (C/2)(dT_o/dt) \qquad (4)$$

This heat-balance equation says that heat in (Q) equals heat out to the right plus the heat stored, where $Q = q_oA$.

When T_o reaches T_M, the boundry condition must

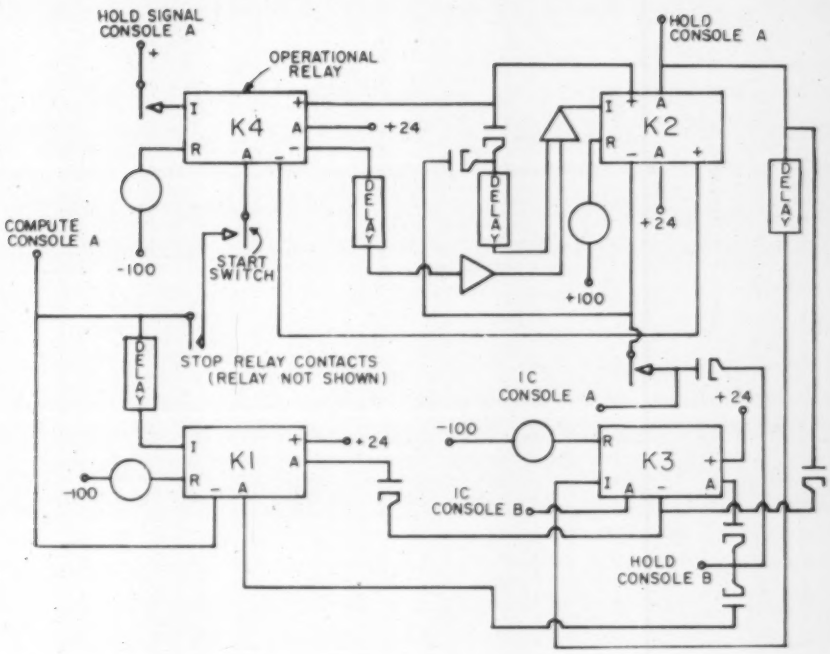

FIG. 4. SYNCHRONIZATION of consoles A and B with the relays.

be modified to include the effect of propagation of the melting surface. A heat balance for the cell (1) is:

$$\rho LA(dS/dt) = Q + K'(T_1 - T_M) \qquad (5)$$

This heat balance says that change of heat required for melting must equal heating from left boundary plus the heating from right, and gives rate at which surface S advances. The total conductivity (K') of one cell and the total cell heat capacity (C') depend in a time-vaying manner on the propagation distance (S) of the moving boundary. As shown in Fig. 2, the total conductivity between the first two cells and the total heat capacity of cell 1, respectively, are

$$K' = kA/(\Delta x - S) \qquad (6)$$

$$C' = \rho C_V A(\Delta x),\ S < \Delta x/2 \qquad (7)$$

$$= \rho C_V (A/2)(3\Delta x - 2S),\ \Delta x/2 \leqslant S \leqslant \Delta x.$$

Note that although melting starts when T_o reaches T_M, there is an immediate influence only on the total conductivity K'. The total heat capacity of cell 1 is unaffected until the half cell, 0, has been melted. The differential equation for the propagation distance S of the moving boundary is

$$dS/dt = (q_o/\rho L) + (k/\rho L)[(T_1 - T_M)/(\Delta x - S)] \qquad (8)$$

When S is equal to Δx, one-half of cell 1 has been melted. The propagation of the melting front proceeds from cell to cell by a repetition of this process. Thus the melting phenomenon is simulated incrementally.

Simulation

The simulation of the melting process at the boundary requires a special analog-computer circuit which must be switched from cell to cell. To avoid mechanical switching of the ablating circuit to each cell, sequentially, we can translate the slab element past the melting circuit through the use of analog memory.

As this simulation was implemented with a two-console computer without external mode control, it was decided to use one of the consoles as an R-memory bank. The two consoles can be synchronized with switching and delay circuitry so that the desired mode of operation is obtained for each console. The duty cycle required to operate the equipment in this manner is shown in Fig. 3, together with the synchronizing circuit (Fig. 4).

If console B is in the IC mode of the operation while console A is in the compute mode of operation, any integrator output from console A can be stored by applying the output of the integrator to the IC terminal of an R-Memory unit (integrator) in console B.

The standard EDA integrator has a 0.1-second time-constant in IC. Thus, whenever it is desired to hold (remember) a variable, it is necessary to place console A into the hold mode until the R-integrators in console B have stored the desired voltage (Fig. 3). At this time console B is placed

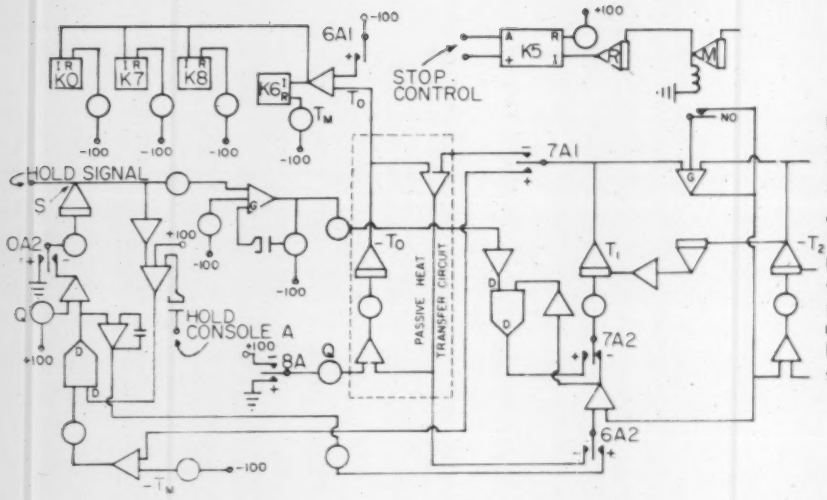

FIG. 5. MELTING CIRCUIT. Passive unit represents first cell until T_0 reaches T_M. When T_0 reaches T_M, K6 operates and holds. Units at lower left solve equation 8. Unit at right solves for T_1 (temperature at first node to the right of melting surface), and T_2 (temperature at next node). When S reaches Δx, computer goes into hold and T_2 becomes next T_1 signal.

in the hold mode while console A reverts to the IC mode, during which the information from the R-integrators is used to establish new initial conditions of parameters in console A. The M-integrators require a similar storage delay. The duty cycle provides the necessary timing for both the R- and M-integrators. Note that the console A is used simultaneously as a computing unit and an M-memory bank.

Consoles A and B initially will be in the IC and hold modes, respectively. When the start switch (see Fig. 4) is depressed, the problem solution begins as console A goes into the compute mode. When T_0 reaches the limiting value T_M, the melting circuit replaces the passive heat transfer circuit as shown in Fig. 5. This circuit is made operative throughout the rest of the simulation with the use of holding relays (K6, K0, K7, K8).

After the melting circuit is energized, S is determined from equation 8. When S reaches the value Δx, the melting surface has propagated to the center of cell 1, and the melting circuit is calibrated so that T_1 equals T_M simultaneously. At this time console A goes into the hold mode.

Note that the hold signal is obtained from the output of the S integrator rather than a comparison between T_1 and T_M. This technique provides a more accurate determination of the melting time (assuming the node spacing for the problem has been specified correctly). As the differential equation for S depends on the heat transfer between cells 1 and 2, inaccuracies in the transient solution of the problem will lead to an erroneous determination of the melting time. Since this error accumulates as the cells are melted successively, the selection of node spacing for the problem is of paramount importance; the existence of a criterion[1] to determine this spacing permits the simulation of the melting problem by this technique.

While console A is in the hold mode, the R-integrators in console B store the temperature profile of the remaining slab element. When console A reverts to the IC mode, these temperatures become a new set of initial conditions for the temperature integrators in console A. At this time an essential translation of the slab element of one cell toward the melting circuit occurs—that is, the temperature represented by the output of the integator n becomes the initial condition for integrator n−1 before the next computation cycle is initiated.

A typical three-amplifier-per-node simulation with this type of initial-condition transfer is shown in Fig. 6 (equation 3). Note that during the next computation cycle the output of the integrator formally associated with T_{n-1} now represents T_n. If, during the first computation cycle, the boundary condition $Q = 0$ is imposed to the right of node m, then during the subsequent cycle this same condition must be imposed by the nodes m and m−1. This is accomplished by a group of relays which are activated by the M-integrators, as shown in Fig. 6. During the second computation cycle the melting surface will propagate from the center of cell 1 to the center of cell 2. As before, when $S = \Delta x$, console A will be automatically placed in the hold mode, and once again the initial-condition transfer will occur. This procedure is automatically repeated until the melting surface has reached the center of the last cell, at which time the simulation is complete and the computation process automatically stopped.

Results

The technique was employed to simulate a slab with realistic parameters. Results are shown in

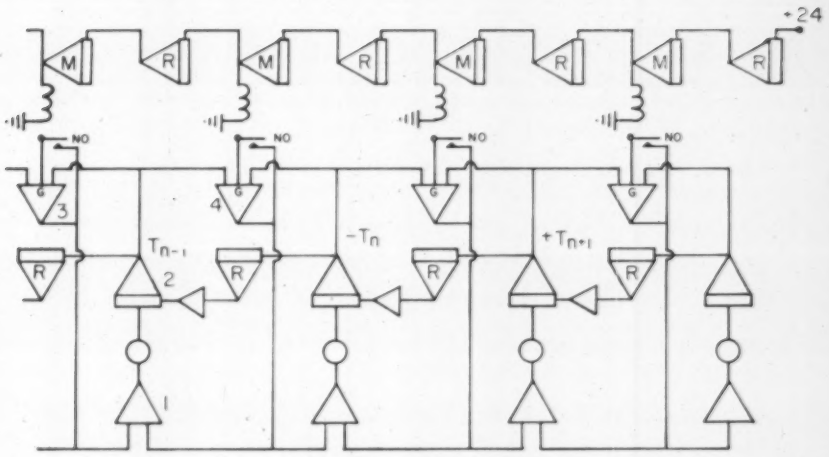

FIG. 6. SIMULATION of equation 3 requires amplifiers, 1, 2 and one-half of 3 and 4. Data comes in from the right after each section melts. Chain at top moves the right (insulated) boundary condition to the left at each cycle.

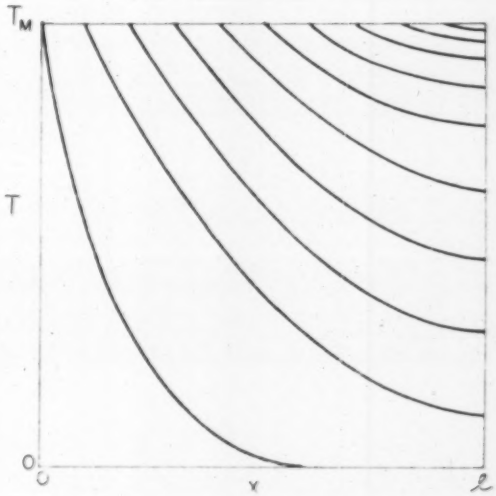

FIG. 7. TEMPERATURE profile.

Figures 7 and 8.

Although the solution for the transient problem cannot be readily verified, the total melting time required for this simulation agreed with the theoretical value within 0.1%. This implies that the transient solution was closely represented due to the method used for calculating the location of the melting surface.

Even though the simulation supposed a constant heat flux over the melting surface and constant diffusivity, the same technique can be used under more general conditions. The success of the method depends largely on the criterion for the determination of node spacing, instead of the mathematical relationships involved with a specification of boundary-layer heat transfer. These results also have a significant interpretation in terms of digital techniques for treating the ablation problem. Even if the diffusivity of the slab is temperature- or time-dependent, the same technique can be employed. This follows from the fact that the most severe transient thermal environment occurs between the first two cell centers; it is necessary only to establish the distance between these centers as the uniform node space for the remainder of the slab. The node-spacing criterion for the case of constant diffusivity of heat transfer can be applied iteratively to determine the lattice interval for the melting problem with nonlinear diffusivity.

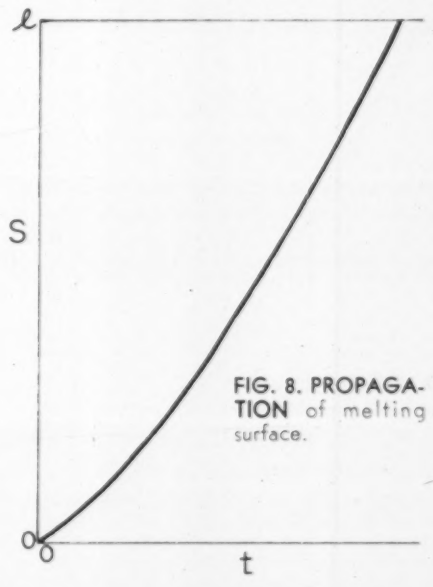

FIG. 8. PROPAGATION of melting surface.

References

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2. MacNeal, R. H., "An Asymmetrical Finite Difference Network," Quarterly of Applied Mathematics, Vol. XI, No. 3; October, 1953.

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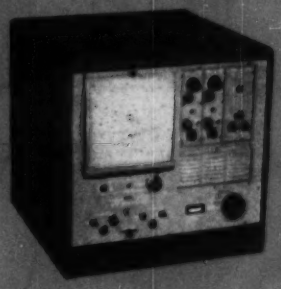


SPECIFICATIONS

Input: single-ended or push-pull

Input Impedance: 5 megohms from each high input terminal to ground with 850-1300B preamplifier

Frequency Response: to 130 cps within 3 db at 8" peak-to-peak deflection

Sweep Rates with Time Base Generator: from 0.01 to 2 seconds

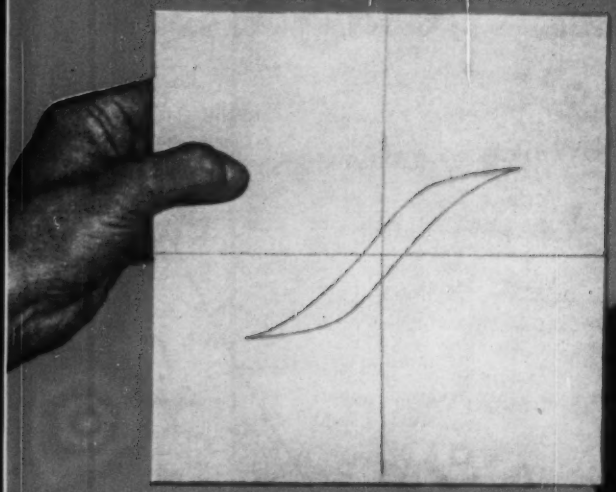
Output Drift: 0.04 inch/hour with 850-1300B

Packaging: Optional cabinet 21¼" x 20" x 20" high, or can be rack mounted in 15¾" of panel space

Power Requirements: 450 watts, 115 volts, 60 cycles AC

Ask your local Sanborn Sales-Engineering Representative for complete information on the Model 670A X-Y Recorder, or write the Industrial Division in Waltham, Massachusetts.

Record 100th-of-a-second X-Y variables directly



- *at 2500"/sec. writing speeds*
- *on 8" x 8" charts*
- *with 1% linearity*
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HYSTERESIS IN MAGNETIC COIL. This plot of magnetomotive force vs. flux density was recorded on the Sanborn Model 670A X-Y Recorder. The complete trace was made in 1/60th sec.

SANBORN COMPANY

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175 Wyman Street, Waltham 54, Massachusetts

CIRCLE 82 ON READER-SERVICE CARD

REPETITIVE ANALOG COMPUTERS AT THE UNVERSITY OF ARIZONA

GRANINO A. KORN, University of Arizona

REPETITIVE electronic analog computers are fast-time-scale differential analyzers which can be reset to initial conditions and can produce solutions as functions of time periodically at rates between five and several hundred computer runs per second. Periodically repeated solutions can be displayed on a cathode-ray oscillograph at eye-persistance repetition rates, so that parameters or initial conditions can be varied manually and can be conveniently observed on the oscilloscope screen.

More recently, electronically switched analog storage units (really integrators in the HOLD condition) have been used to introduce results from earlier runs into subsequent runs, so that the fast all-parallel operation of the analog computer is combined with sophisticated sequential programming schemes. As an example of particular interest to our own development work, the Monte-Carlo technique developed by Van der Velde of GPS Instrument Co., Inc., introduces random initial conditions, parameters, and/or random forcing functions into successive computer runs; solutions from different runs are sampled at corresponding times, and functions of these samples are averaged with associated computing equipment to produce estimates of ensemble statistics such as probabilities, averages, mean squares and correlation functions. The fast computation rates of repetitive computers are particularly useful in connection with such statistical studies. Thus, a thousand simulated missile runs can be made in minutes if a 20-cps repetition rate is available.

The development program at the University of Arizona attempts to study many of the aspects of fast semiautomatic analog computation, with particular emphasis on the Monte-Carlo techniques mentioned. The study is to culminate in the development of a fairly large (20 to 40 amplifier) repetitive computer specifically designed for techniques of this type.

Another application of special interest is the use of the fast computer in control systems with "two-time-scale" or "predictive" control.

Accuracy

In considering the design of any analog computer, the question of accuracy comes into play. The question of accuracy prediction is sufficiently difficult for high-quality slow analog computers, but with fast repetitive analog computers, phase shift due to bandwidth limitations becomes a paramount consideration. The attractions of fast sequential computation cannot conceal the fact that bandwidth limitations can make computed results all but meaningless unless the problem has been carefully chosen in relation to the computer specifications. The author believes that extreme caution is necessary in using repetitive operation at rates greater than a few cycles per second with modified "slow" analog computers. The reasons for this caution are bandwidth limitation errors, due not so much to the computer's operational amplifiers as to capacitances in patch bays, interunit wirings, and, particularly, in the coefficient potentiometers. A big question is the frequency response actually required of the entire system.

Timing errors encountered even with 1-millisecond relays make electronic switching almost mandatory at repetition rates in excess of 5 cps.

Theoretical studies on the bandwidth limitation accuracy of linear simulated systems have been made by MacNee, Dow, Marsocci and, lately, by C. H. Single. These studies indicate that reasonable accuracy can be expected for linear-system solutions which involve only highly damped normal modes. If pure sinusoidal oscillations occur (and this is true, for instance, in simulated oscillations of structures), fast computation will lead to errors

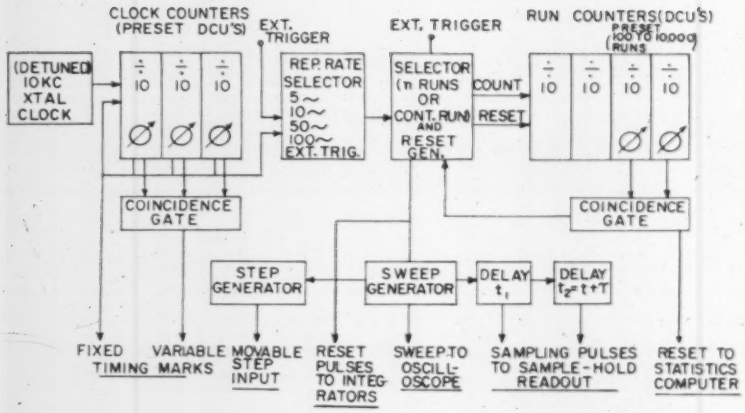


FIG. 1. PROPOSED timing and control for repetitive analog computer.

such as the familiar decay or increase of the amplitude in a three-amplifier sine-wave-generator loop. In addition to this effective displacement of normal-mode complex frequencies, additional fictitious modes may appear and can lead to computer instability; we hope to study this question in more detail in connection with specific computing equipment and with specific problems.

Highly damped simulated linear servos can be studied with some degree of assurance. The question becomes much more difficult if complicated nonlinear effects involving multiplication, limit stops and other function generation are considered. In this case, unfortunately, inaccuracies due to bandwidth limitations are further aggravated by the basic inaccuracy of multipliers and function generators capable of operating at reasonably high frequencies.

The prediction of solution accuracies in complicated nonlinear problems is extraordinarily difficult and is probably best made in individual cases by an error analysis, or by checks with digital computers or "slow" analog computers. In statistical problems, statistical averaging will average out certain errors but not others, so extreme caution is necessary in this case as well.

If dynamic storage is used for sequential programming of fast and slow computer runs, intelligent program design might permit correction of the "fast" computing elements by the more accurate "slow" ones. Such techniques are, of course, no longer straight-forward simulation techniques but require more sophisticated analysis.

Preliminary Design

In view of the bandwidth limitations, we have concluded that, for a reasonably versatile computer, it is necessary to develop a repetitive analog computer specifically for the purpose of fast-time-scale computation. To avoid unnecessary circuit capacitances to the greatest extent possible, one has to give up the use of conventional patch bays and, unfortunately, also the use of removable boards, so as to have short connections to amplifier input and output terminals. A very careful patch-bay layout will permit most patching connections to be short and direct; all patching connections will proceed from left to right with right-to-left connections made with low-capacitance buses in the machine for uncluttered computer setups.

The use of low impedance levels requires amplifiers which have not only good high frequency response but also a reasonable current output; a ±50-volt dynamic range was chosen in order to make such operation easier on amplifiers of economical size.

Coefficient-setting potentiometers or attenuators constitute a particularly nasty source of phase shift. We shall probably use two-turn film-type potentiometers of reasonably low resistance such as 25 K.

Front-panel modules combine groups of printed circuit amplifiers individually removable to the rear. Each functional group comprises:

2 summer-integrators
1 summer
1 phase inverter
4-6 coefficient potentiometers (used also to set initial conditions when needed)

This corresponds to one typical dynamical-system equation or two chemical-type equations. Summer and integrator inputs will permit various combinations of input gain. Probably all will have input impedances equal to 100K.

Amplifier Design

A study of the subject revealed that none but the relatively expensive GPS Instrument Co. amplifiers had the bandwidth and power required for our purposes. As we also needed faster operational amplifiers for other projects concerned with fast electronic switching operations, amplifier circuits were developed at the University of Arizona.

Model 1 is a two-envelope amplifier maintaining a gain of 1,000 out to 10 kc; output is 5 ma at ±100 volts. At low frequencies, regeneration raises the gain to some 30,000. This amplifier is directly

interchangeable with the Philbrick K2X amplifier and can be chopper-stabilized with a standard Philbrick K2P chopper stabilizer.

Model 2 is a gain-of-100 amplifier with 10-ma output and maintains its open-loop gain up to frequencies of about 10 kc. It is also directly interchangeable with standard Philbrick plug-ins and is particularly useful by itself for fast switching applications.

Model 1 and Model 2 can be cascaded with a standard chopper-stabilizer circuit to make a repetitive-computer amplifier of remarkable performance and relatively low cost. Closed-loop gain even without compensating capacitors around the summing resistors is still useful at frequencies above 500 kc. The d-c gain exceeds 100 million, and 10 ma can be obtained at ±100 volts out to 50 kc. The rise time for positive and negative 80-volt pulses is 2 microseconds. Note that our three standard plug-in units (Model 1, Model 2 and the Philbrick K2P) can be combined into many other useful circuit combinations. We are now contracting for printed-circuit boards for 40 of the complete cascade units for use in our repetitive analog computer. It is estimated that the cost to us of a complete amplifier will be below $100, including five vacuum tubes and one Airpax chopper.

Control Circuits

The timing system (Fig. 1) is derived for convenience in construction entirely by digital circuitry, using low-cost decimal counting units.

Reset pulses are derived by counting down from a 10-kc crystal oscillator which is detuned slightly in order to avoid a harmonic relationship with the line frequency, which might prove disastrous in statistical computations.

Pulses from the same counting chain also will be used for calibrating the oscilloscope time axis with marker pips or timing marks. Push-button controls will permit selection of statistical samples of between 100 and 10,000 computer runs.

The readout system will involve sample-hold circuits permitting one to read out samples of variables at calibrated times t_1, t_2, . . . after the start of each computer run. These times t_1, t_2, . . . can be set on digital-indicating dials, and can also be controlled by voltages, so that automatic programming is possible. The samples from each computer run can be read to a digital voltmeter permitting direct digital readout. We consider this method to be more convenient (as well as more accurate) than provision of a voltage-calibrated television-type display.

A readout switch on each amplifier will connect the output of that amplifier to a sample-hold circuit which can, in turn, be connected to read out through a digital voltmeter, printer, recorder, or to the statistics computer. Similar readout switches will also be used to set coefficient potentiometers and initial conditions. Simple alarm circuit will prevent simultaneous connection of two voltages to the same sample-hold circuit.

Note that sampler outputs can be displayed on an accurate servo table or strip-chart recorder, so that a variable can be plotted against the sampling time t_1 or against another variable.

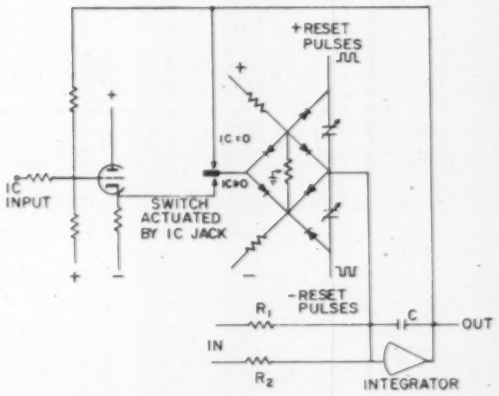


FIG. 2. INTEGRATOR-RESET CIRCUIT.

When random inputs are used, the sample-hold circuits deliver samples $x(t_1)$, $y(t_2)$, etc., to a statistical computer which performs the operations required for the calculation of correlation functions, probabilities, etc.

Resetting Initial Conditions

Electronic resetting is being done by means of a six-diode switch shown in Fig. 2. The initial-condition circuit shown does not require addition of initial conditions in a subsequent amplifier. (This circuit was checked out as an undergraduate term paper.)

All amplifiers used in the computer will be chopper stabilized and have no balancing knobs. The diode switches used for integrator resetting and in the sample-hold circuits do require a screwdriver balancing control, but it is expected that frequent balancing will not be necessary.

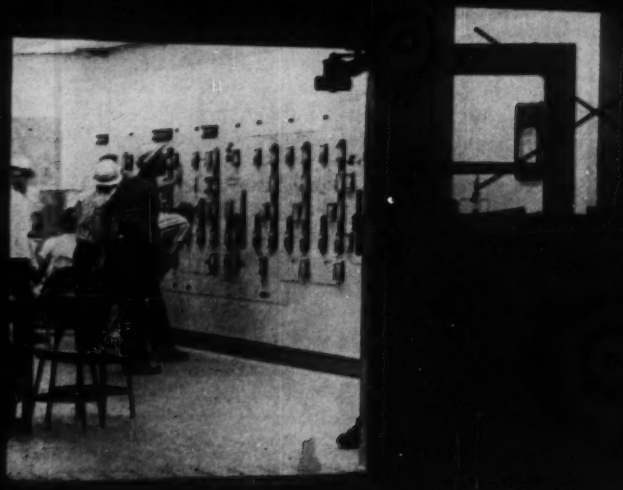
Nonlinear Circuits

The type of multipliers to be used in the repetitive computer is still undecided. Most multipliers operated at high frequencies are inaccurate; perhaps an improved quarter-square or triangle-integration multiplier will be satisfactory, or an FM-AM multiplier with increased carrier frequency can be adapted. This is a tough problem and has much to do with our decision to use relatively low repetition rates (as low as 5-10 cps).

Diode function generators (under development) will be used. A new noise generator uses a radioactive source and scintillation counter to produce random square waves as well as flat-spectrum noise out to 20 kc. We are still checking for 60-cps components, but could get rid of them by sampling at a frequency not harmonically related to the line frequency.

12:30 A.M.

Everything's under Control!



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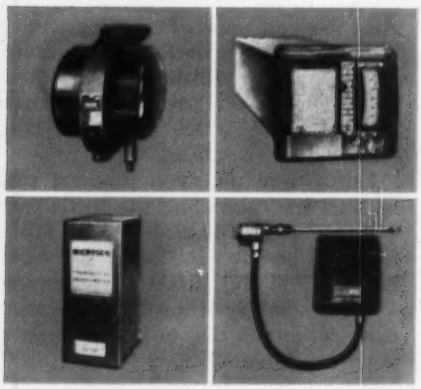

Shown above: (Top, l. to r.) Microsen Transmitter, Microsen Recording Controller. (Bottom) Microsen Transmitting Potentiometer, Level-Tek Level Detection and Control System.

Robertshaw

Aeronautical and Instrument Division
Robertshaw-Fulton Controls Company,
Santa Ana Freeway at Euclid Avenue
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CIRCLE 83 ON READER-SERVICE CARD

Calibrating Analog-Computer Integrators

If computer integration accuracy of 0.01% is to be maintained, special procedures must be used. Compensation must be made for time-constant factors, capacitor factors, and relay factors. Accurate adjustment of the integrating capacitors is the most difficult task.

R. P. SYKES, Martin-Denver

INTEGRATORS must perform accurately under two different conditions. First, when the computer control switch is thrown to *operate* (operate mode), we expect the integrator to accumulate a known input voltage at a precise rate per unit time, so that its output is the exact product of input voltage and time. This is *specialized integration* with time as the dependent variable. Second, when the computer control switch is thrown to *hold*, we expect all integrators to stop integrating simultaneously, and retain the output voltage accumulated up to the instant the hold switch was thrown. This is the *hold mode*.

Integration Errors

Fig. 1 is a simplified schematic of an integrator, showing the sources capable of contributing error to the integration. These error sources are: (1) I.C. (initial-condition) summing and feedback resistor match, (2) input-resistor feedback-capacitor time-constant match, (3) feedback-capacitor dielectric absorption, and (4) operate-relay closure-time match and contact resistance.

I.C. Resistors

I.C.-resistor mismatch results in an incorrect initial voltage being stored in the feedback capacitor. These resistors are tested and adjusted in the same manner as the summing resistors discussed previously.[6]

Time-Constant Match

The input-resistor feedback-capacitor time-constant match must be identical on all integrators, or an error will result in the dynamic performance of the integrator, as shown in Fig. 2. In this example,

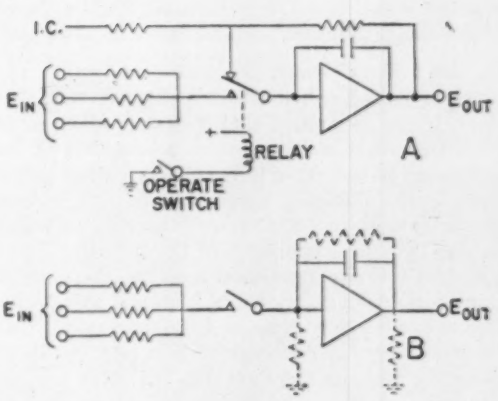

FIG. 1. SIMPLIFIED integrator schematics. A shows initial-condition and operate mode. B shows hold mode, with leak paths shown as resistors.

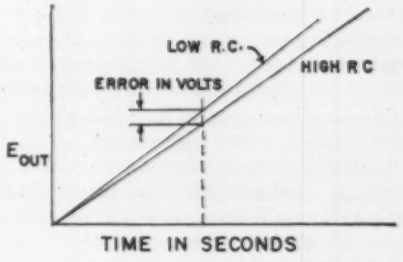

FIG. 2. TYPICAL error from time-constant mismatch.

The work described was performed while the author was with Space Technology Labs, Inglewood, California.

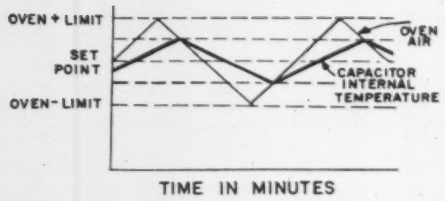

FIG. 3. CAPACITOR temperature lags oven air temperature, reducing temperature deviations of the capacitor.

FIG. 4. CAPACITOR temperature deviations are further reduced by speeding up the oven cycle.

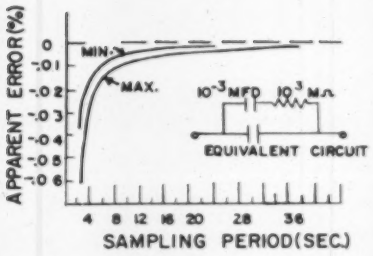

FIG. 5. SHIFT in capacitance due to dielectric absorption, and equivalent circuit of a 1-uf polystyrene capacitor (after Single).

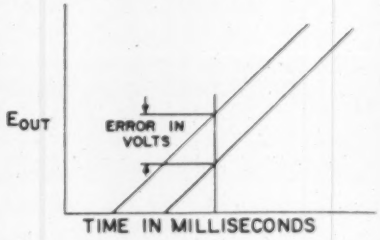

FIG. 6. IF RELAYS do not close at same instant, a difference error in integrator outputs results.

we don't know which integrator is "right" and which is "wrong"; obviously they disagree with each other. It can be argued that it doesn't make much difference what the nominal time-constant of the integrators is, so long as they are all identical within close limits. Within a given console this is true, inasmuch as the integrators are the only reference to time that the computer has. On the other hand, if several consoles are slaved together, the nominal time-constants of each must be identical. It is preferable to use standard time as a standard rather than use some arbitrary reference such as one "standard" integrator because there are some accurate primary standards of time available for reference and nothing to check an arbitrary standard against.

Oven-Temperature Control: Temperature Coefficient

It will prove fruitless to attempt the adjustment of integrator-time-constant match unless the oven temperature is controlled satisfactorily. The need for adequate oven-temperature control can be demonstrated by examining the temperature coefficient of capacity for the best available polystyrene integrating capacitors, which is -100 PPM/°C. As 100 PPM is 0.01%, an oven regulated to ± 1°C will cause the time-constant mismatch to vary ± 0.01%. When slaving computer consoles, if one oven is at the maximum temperature when the other is at the minimum, resulting in oven temperatures differing by 2°C, integrator mismatch will be 0.02%.

Matching Opposing Temperature-Coefficients

It has been suggested that resistors having a positive temperature coefficient of resistance be used with polystyrene capacitors whose temperature coefficient is negative. This combination would result in a time constant insensitive to temperature changes to the point of obviating the need for an oven. This theory falls down in practice because the thermal lag of the resistors is of the order of five minutes, while that of the capacitors is three to five times as much. Consequently, no matter what the period of the oven temperature control, the resistor and capacitor find an equilibrium temperature difference.

No accurate satisfactory solution to this measurement problem has been found; it is hoped that this discussion will provoke additional suggestions.

Controlling Oven-Air Temperature

As shown in Figs. 3 and 4, the thermal lag of the capacitors relative to the oven air is greater as the time constant of the oven temperature increases. If the frequency of the oven temperature limit cycle can be increased, an increase in thermal lag will result for a given peak-to-peak temperature excursion (Fig. 4). Since it is easier to increase the frequency of the limit cycle, such as by increasing heater dissipation, than to decrease the peak-to-peak temperature excursions, this would appear to be the least expensive way to improve capacitor stability. However, as the oven-control thermostat has a thermal lag also, an increase in frequency results in the thermostat lagging the oven-air temperature, with an increase in peak-to-peak temperature excursion. The problem appears difficult to optimize by analytical means. It was also suggested that, due to the inaccuracies associated with the

measurement of the required constants, the analytical result would contribute little to the achievement of absolute optimization.

Anticipatory Control

It is desirable to reduce the lag between the oven-temperature sensing thermostat and the oven-air absolute temperature, with the consequent advantageous increase in limit cycle frequency. Perhaps the best method of decreasing the *apparent* lag between the thermostat and the air is to install the thermostat near the heaters, so that it receives much of its heat directly from them, bypassing the intermediate air. Since the air lags the heaters, and the thermostat and capacitors both lag the air, it is possible, by coupling heat from the heaters into the thermostat, to eliminate most of the lag between the thermostat and heaters. The thermostat is then said to *anticipate* the temperature of the air, controlling the heaters to correct a change in air temperature almost before it has occurred.

Another way to couple the thermostat to the heaters is to mount a small power resistor beside the thermostat and connect it in parallel with the heaters. This couples heat directly into the thermostat when the heaters are on and accomplishes the same effect, at greater thermal efficiency and less complication, than moving either the thermostat or heaters.

Another method of achieving anticipatory control uses two operational integrators—a thermocouple heat transducer and an ice-bath reference. It achieves the same operational dynamics by electronic analog but is too complex for the usual installation.

Unfortunately, anticipatory control reaches a limit of usefulness at the point where the thermostat is maintaining the heaters at a constant temperature, instead of the air. If the heat loss from the oven were constant, this would be a desirable objective, obtainable more easily by voltage regulation of the heater input power. However, the losses from the oven are variable, depending on room temperature, power dissipation by the oven components, number of patchboard connections, etc.

Dielectric Absorption

Feedback-capacitor dielectric absorption is only of academic interest because it cannot be adjusted or minimized. However, it can account for about 0.05% variation in results obtained under different test conditions.

When a capacitor is connected to a source of voltage, the charging current decreases to a small but measurable residual current, caused by charge being absorbed by the dielectric material. Conversely, upon discharge, a small residual discharge current continues for some time after the initial discharge. Mr. Single[2] has measured the change in capacitance due to dielectric absorption (Fig. 5). Note that the apparent shift in capacitor value is a function of the duration of test. Clearly, any test of capacitance value should be extended over a period of at least 8 or 10 seconds; the same time should elapse between successive tests to insure complete discharge.

However, if the capacitor is to be used in the computer at rates of charge and discharge faster than 8-10 seconds, it may not be realistic to adjust integrators to this time base. The period selected should represent the best compromise.

Relay Closure Time

Relay closure-time mismatch will result in an error of the type shown in Fig. 6.

If we assume integration at the rate of 100 v/second, a relay timing difference of 1 millisecond (0.001 sec) will cause 0.001 x 10 v = 0.1 volt difference in outputs. This is 0.1% of 100 v. The higher the integration rate, the higher the error. As rates of 100 v/second are being used in conventional computer solutions, relay timing errors must be minimized.

We have refitted our relay networks with a relay* which operates in 300 μsec with a maximum differential between relays of about 100 μsec.

Relay Contact Resistance

Recent Bell Labs investigations[5] led to the discovery that, at currents less than about 100 μamp, the contact resistance of most relays will be in the order of 1000 ohms, with 500 ohms as a minimum and 10K as a maximum. Assuming a summer or integrator with 1-meg input resistor, and assuming the summing junction to be a virtual ground, it takes 100V through the 1-meg and relay contacts (to ground) for 100 μamp to flow. This means that there is 1000 ohms in series with the summing resistor over much, if not all, the voltage range of the computer. 1000 ohms is 0.1% of 1-meg, and 1.0% of 100K (10-gain input). Therefore the actual gain of a 10-gain input may be as much as 1% in error, despite precise adjustment of the network resistors.

The careful cleaning of the operate relay contacts will reduce the voltage required to break down this resistance, but will not improve the magnitude of the resistance itself. The improvement in threshold voltage for breakdown is rarely better than 10 times, or from 100v input to 10v input through 1-meg, corresponding to 100 and 10 μamps, respectively. As a 0.1% discontinuity in gain occurring at 10 volts in a 1-gain circuit is still intolerable, measures other than cleaning are indicated.

Mercury-wetted contacts, and malleable gold contacts are the only two known instances where this phenomenon is not found. Mercury-wetted contacts are not available in relays operating much faster than 1-msec. The 300-μsec relay mentioned previously does have malleable gold contacts. In this relay the contact force is high enough to actually deform the surface of the contact material, breaking down the resistive film. Maximum contact resistances of 0.1 ohm have been measured, and are guaranteed by the manufacturer to not be exceeded.

*Made by the Bristol Company, Waterbury, Conn.; it is available as Type C-1422

Integrator Error Measurement

The measurement of input-resistor feedback-capacitor time-constant match has been the subject of some thought, both by the author and by others[2, 4]. The Princeton Computation Center uses[4] a circuit (Fig. 7) involving the summation of the outputs of several integrators. The summing point thus obtained is connected in parallel to all inputs under consideration. The 100V I.C. appears at all outputs (modified by the mis-match in I.C. resistors) and is connected to the inputs sequentially (non-simultaneously) by the various operate relays. The result, when integration ceases, is zero voltage on the output summing point, as the outputs of all integrators add to zero. Reading the output of the individual amplifiers gives the deviation of each from the mean.

Mr. Single, of Berkeley, mentions three schemes in his paper[2]. One of these is the frequency method (Fig. 8,A), which uses a three-amplifier oscillator with a standard capacitor around one integrator and the unknown around the other. Frequency of oscillation is measured using an Eput meter.

Single's second method is called the step-ramp method (Fig. 8,B). This involves applying a constant input voltage and measuring the time for the output to reach a certain value.

His third method, a modification of the second, is the ramp-parabola method (Fig. 8,C). A linear ramp input voltage, instead of a step, causes the output to rise parabolically; hence the name.

Integrator Error in Hold

Errors when an integrator is in the *hold* mode are caused by the accumulated charge leaking off the integrating capacitor. The causes are (1) internal leakage of the capacitor, or insulation resistance, (2) leakage external to, but in parallel with the capacitor, and (3) leakage from the summing junction to ground (Fig. 1B).

Internal leakage is primarily a function of the dielectric in the capacitor. With polystyrene, a figure of 1×10^6 megohms is typical for a 1-μf capacitor. Moisture and contaminants can lower this figure.

One source of *external leakage* is the sum of the leakages across both insulator terminals of the capacitor. These insulators usually are glass and about ¼" long. The leakage path in parallel with the capacitor is therefore ½" of glass. Compared to 10^6 megohms, this external leakage can be large.

The remainder of external leakage is contributed by the coax cables connecting the summing junction of the integrator network to the grid of the amplifier. New cables will measure in excess of 10^5 megohms, but old cables dry out and crack when moved, permitting the moisture and contaminants to lower the resistance to 10^3 megohms. The connectors on the ends of the cables are a particular troublespot because the rosin from the solder used to connect the shield to the connector can (with several types) flow back under the shield to the center pin, and eventually contribute to the leak. Crimp-type connectors are superior to solder type in this respect.

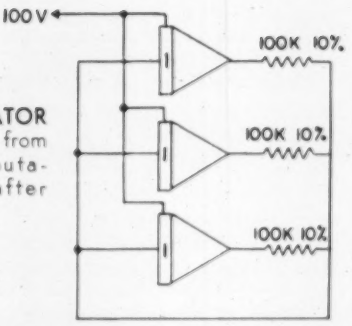

FIG. 7. INTEGRATOR test schematic from Princeton Computation Center (after D'Arcy).

Testing Integrator Leak

The best test for total system leak is to operate the integrators up to 100 volts, place them in hold, and monitor their outputs with the digital voltmeter. Since $T = RC$, and $C = 1\ \mu f$, $T = R$ in megohms. For small intervals, the approximation $1/T$ is valid for computing R. Therefore, if we observe a leak of 0.01 volt in 10 seconds, the initial rate of discharge would correspond to 100 volts in 10^3 seconds, indicating a leak resistance of 10^3 megohms. Since something approximating 10^6 megohms seems reasonable to obtain, 0.01 volt in about 100 seconds would appear to be about the minimum leak rate possible.

The Southwestern Industrial Electronics Model C-6 megohmeter is valuable in isolating sources of leaks. This instrument will indicate 2×10^7 megohms.

Adjustment of Capacitors

Eventually it is necessary to adjust the integrating capacitors. This seemingly simple step is hazardous.

Adjustable capacitors usually have a ¼-20 Allen-head cap screw in an anti-vibration nut. The screw presses against a ball bearing which compresses the stack of capacitor plates and dielectric material.

Variations in the following phenomena make the accurate and permanent adjustment difficult or impossible: (1) Breakway friction between anti-vibration nut and screw, (2) roughness of end of screw, or ball seat (dimple in top plate of pile), (3) pitch of screw, (4) cold flow of dielectric, and (5) temperature coefficient of capacitor.

Breakaway friction limits the minimum incremental change in capacitance that can be made. When sufficient torque is applied to overcome friction, the sudden rotation gives a stepwise change in capacitance on the order of 0.01%.

Roughness of screw and ball seat tend to modulate the pressure on the ball as the screw is turned. As the ball moves about on the dimpled pressure plate in which it rides, it rolls into and out of depressions in the metal. This causes random change in capacitance as the screw is rotated, which approximates 0.005%. Thus, a minimum clockwise rotation of the screw may cause an increase in capacitance from 0.005% to 0.015%, due to the combined effects of breakaway friction and roughness.

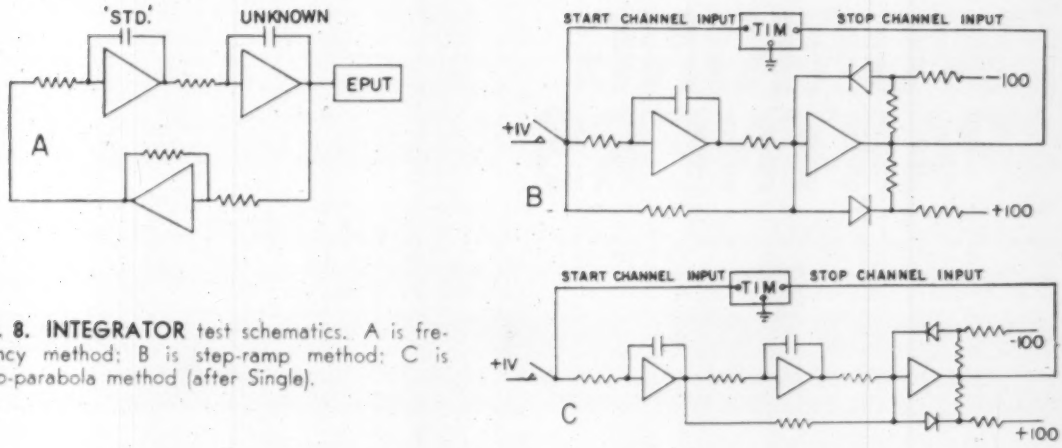

FIG. 8. INTEGRATOR test schematics. A is frequency method; B is step-ramp method; C is ramp-parabola method (after Single).

Pitch of screw is such that only three turns of the screw cover the complete 1% range of adjustment available. As a ¼-20 screw advances 1/20" (50/1000") for each turn, the adjustment range is covered with 150/1000" or 0.15" compression. Some recent capacitors have a 4-40 screw threaded through the center of the ¼-20 bolt. This "fine-adjust screw" compresses 1/40" per turn, or just half as much as the bolt does, resulting in six turns for 1%, or approximately 0.16% per turn.

About 1/32 turn is the minimum incremental turn that can be made; this corresponds to about 0.01% with the coarse screw and 0.005% with the fine screw, which represents about the best obtainable.

Dielectric cold flow after compression of the stack will take place gradually over a period of about 48 hours. As the plastic relieves the pressure, the capacitance decreases. This means that the ultimate effect of an adjustment is not measurable within 24 to 48 hours after the adjustment is made. This drift is due to plastic cold flow in the stack. It can be estimated roughly as on the order of 0.01% to 0.02%.

Temperature coefficient affects capacitor adjustment if it is necessary to open the oven door to adjust the capacitors. Some cooling takes place, with a consequent increase in capacity at the rate of 100 ppm/°C. Maximum effect is about 0.2% change in capacitance due to cooling from 100° to 70° F room temperature (30°F change is roughly 20°C, times 100 ppm equals 2000 ppm or 0.2%). In practice, the oven rarely will be open long enough for the capacitors to cool to ambient, but a change of 0.05% to 0.1% should be anticipated.

Improving Adjustability

The combined effects of the foregoing factors make the permanent adjustment of capacitors to 0.01% or better virtually impossible. Minimizing these effects is important.

The first three items are mechanical and cannot be improved in existing equipment.

Cold flow cannot be improved, but its effect should be kept in mind, and final adjustment should be delayed 48 hours for this reason.

Temperature coefficient cannot be improved, but its effects can be minimized by remote adjustment of the capacitors through the door.

In the author's opinion the most satisfactory improvement that can be made is installation of padding capacitors in parallel with the integrating capacitors. For instance, the El-Menco No. 307-M has a range of adjustment of 730 $\mu\mu$f (from 340-1070 $\mu\mu$f). This represents 0.0073% of 1μf. It has a rating of 1000 v, which is ample; its insulation resistance is in excess of 10^8 megohms. Its temperature coefficient is positive (about +100 ppm/°C); 19 capacitors will mount conveniently on a 5"-square board, which should fit into most computers without difficulty.

Adjustment Procedure Using Padders

All padders should be set to minimum capacitance; set all integration capacitors to between 0 and +0.01%. After 48 hours, recheck and readjust until all capacitors are between zero and —0.005%. Then the padders should be adjusted to bring all capacitors "on the nose," which should take less than the full range available. The padders are then available for minor trimming as periodic tests indicate the need for slight readjustment.

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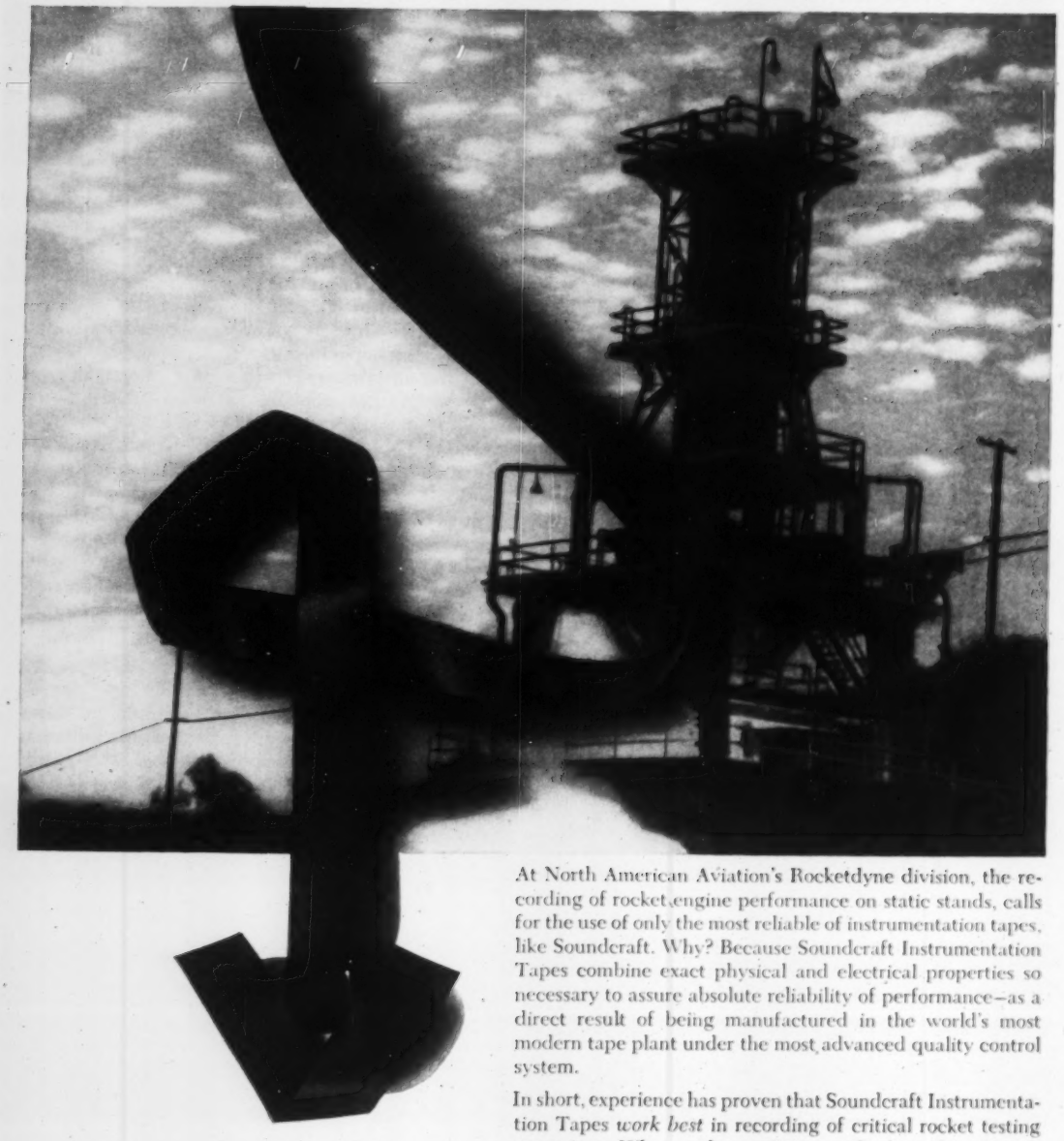

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Analog Solution of Beam Problems

The ease of solving beam problems on an analog computer is an argument in favor of this method over normal numerical methods.

J. N. MACDUFF
Duke University

ANALYZING the vibrational response of multi-rotor shaft systems usually requires the use of tedious methods[1] or a digital computer. The small analog computer, however, permits a simplified approach which is suitable for determining the response of elementary systems by the average design engineer.

Of the methods available, the lumped-parameter system suggested by Professor W. W. Soroka[2] appears to be the most economical in the use of analog equipment. Although this method requires more work in the preparation of the computer program, the final program requires fewer amplifiers and hence a smaller computer than more elaborate procedures.

The initial step is the usual one of reducing the actual system to an equivalent beam system with weightless shafts and rigid rotors (Fig. 1). The influence coefficients now can be found by use of standard deflection formulas[3] or by numerical integration. These influence coefficients give the static deflection of the beam as a function of the rotor weights and shaft stiffness (Fig. 2).

The equation in Fig. 2 gives the deflection (y) for a beam with simple supports and concentrated load (w). It is used to calculate the influence coefficients (a). It is for the portion of the beam from the load to the right-hand end.

The a's are influence coefficients. The first subscript denotes the position of the unit load. The second subscript denotes the deflection location. The deflections are related to the influence coefficients as follows:

$$y_1 = a_{11}W_1 + a_{21}W_2 + a_{31}W_3$$
$$y_2 = a_{12}W_1 + a_{22}W_2 + a_{32}W_3$$
$$y_3 = a_{13}W_1 + a_{23}W_2 + a_{33}W_3$$

The rotor shaft system is then converted to a

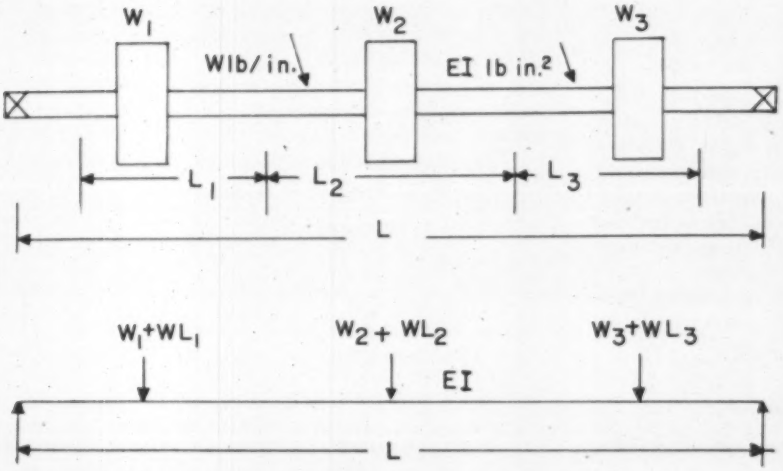
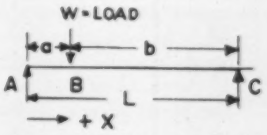


FIG. 1. ACTUAL system of rotors on shaft (top) can be considered as weightless shaft and rigid rotors (bottom). E is Young's modulus (3×10^7 lb/in^2) and I is section inertia (in^4).



$$y_{BC} = \frac{WL^3}{6EI}\,\frac{a}{L}\,\frac{(L-X)}{L}\left[\frac{2b}{L} - \frac{b^2}{L^2} - \frac{(L-X)^2}{L^2}\right]$$

FIG. 2. EQUATION for determination of influence coefficients.

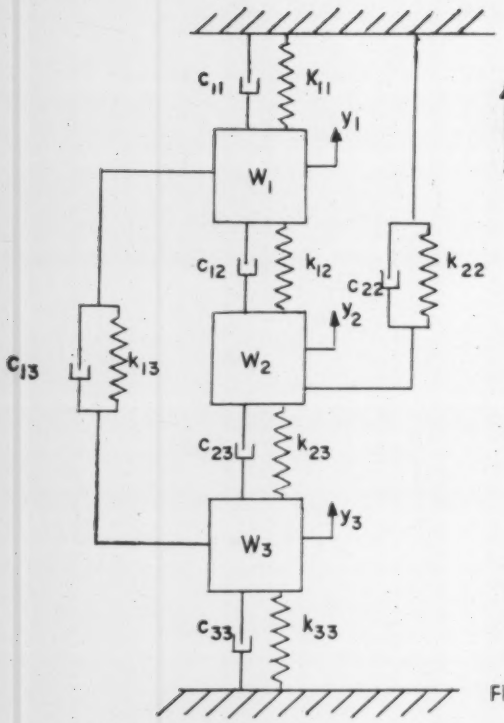


FIG. 3. **EQUIVALENT** lumped system of Fig. 2.

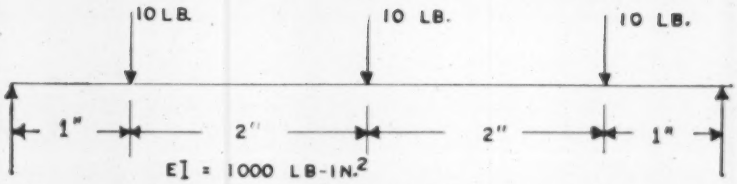


FIG. 4. **IDEALIZED** beam used for illlustration.

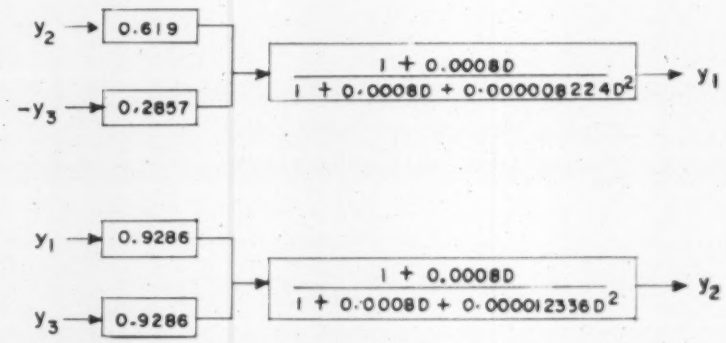


FIG. 5. **BLOCK** diagram and transfer functions for beam of Fig. 4.

lumped-parameter system (Fig. 3). Each rotor is represented by a mass of the same weight, and is connected to every other rotor and to ground by an impedance consisting of a spring and damper in parallel. To determine the spring constants of the lumped system, a unit load is applied in turn to each mass of the lumped system of Fig. 3. The equations of static equilibrium then, are:

$$\begin{aligned} a_{11}k_{11} + a_{12}k_{22} + a_{13}k_{33} &= 1 \\ a_{21}k_{11} + a_{22}k_{22} + a_{23}k_{33} &= 1 \\ a_{31}k_{11} + a_{32}k_{22} + a_{33}k_{33} &= 1 \end{aligned}$$

and:

$$\begin{aligned} a_{11}k_{11} + (a_{11} - a_{12})k_{12} + (a_{11} - a_{13})k_{13} &= 1 \\ (a_{22} - a_{21})k_{21} + a_{22}k_{22} + (a_{22} - a_{23})k_{23} &= 1 \\ (a_{33} - a_{31})k_{31} + (a_{33} - a_{32})k_{32} + a_{33}k_{33} &= 1 \end{aligned}$$

With the influence coefficients known, the solution of equations (1) and (2) will give the spring constants for the lumped system of Fig. 3. Knowing the numerical values of the spring constants and assuming dashpot damping coefficients, it is then feasible to write the differential equations for the lumped system. The differential equations then yield the transfer functions for each rotor.

The beam shown in Fig. 4 will be used to illustrate the procedure. The spring constants determined from equations (1) and (2) are:

$$\begin{aligned} k_{11} = k_{33} &= 2100; \; k_{22} = -1800 \\ k_{12} = k_{23} &= 1950; \; k_{13} = -900 \end{aligned}$$

Assuming that $c_{11}/k_{11} = c_{22}/k_{22}$, etc., $= 0.0008$, the differential equations are:

$$(0.000,008,224D^2 + 0.0008D + 1)y_1 = (0.619y_2 - 0.2857y_3)(1 + 0.0008D) + F/(3150) \quad (3)$$

$$(0.000,012,336D^2 + 0.0008D + 1)y_2 = 0.9286(y_1 + y_3)(1 + 0.0008D) \quad (4)$$

$$(0.000,008,224D^2 + 0.0008D + 1)y_3 = (0.619y_2 - 0.2857y_1)(1 + 0.0008D) \quad (5)$$

where F is the excitation. F is indicated as acting at mass 1 here, but obviously could act on any one or all of the masses.

Re-arrangement of equations 3, 4 and 5 gives the block diagram and transfer functions of Fig. 5. To derive the analog program, the impedance transfer functions of Fig. 6 are used. As the transfer functions of Fig. 5 and Fig. 6 are similar in form, the only problem remaining is determination of the proper values of resistances for the analog program.

Using 1-μf capacitors throughout, the calculations for the analog program of Fig. 7 are:

1. For the y_1 output amplifier:

Time Scale		Full	1/2	1/3
$R_1 = 800/2$	=	400	800	1,200
$R_2 = 8,224,000/400$	=	20,560	41,120	61,680
$R_{1y2} = 20,560/0.619$	=	33,215	66,414	99,645
$R_{1y3} = 20,560/0.2857$	=	71,965	143,927	215,800

2. For the y_2 output amplifier:

$R_1 = 800/2$	=	400	800	1,200
$R_2 = 12,336,000/400$	=	30,841	61,682	92,523
$R_{1y1y2} = 30,841/0.9286$	=	33,212	66,414	99,645

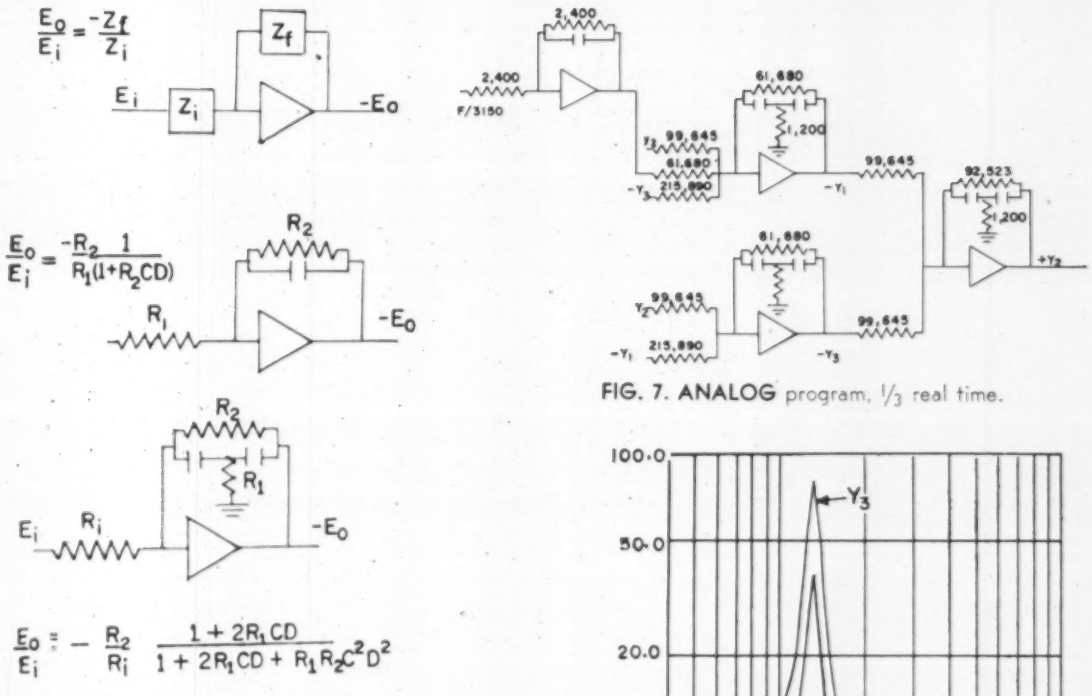


FIG. 6. **IMPEDANCE** transfer of operational amplifiers.

FIG. 7. **ANALOG** program, 1/3 real time.

3. For the F/3150 amplifier:

Time Scale		Full	1/2	1/3
$R_f = 800$	=	800	1,600	2,400
$R_i = 800$	=	800	1,600	2,400

The resistances for ½-time operation are obtained by multiplying all the full-time resistances by 2. This doubles each individual time-constant, and hence the time scale is changed by the same amount (doubling all the resistances leads to analog frequencies that are ½ of the prototype frequencies). In a similar manner, multiplying all resistances by 3 will give analog frequencies ⅓ of the prototype frequencies.

Fig. 8 shows the frequency response of the beam system of Fig. 4 with the excitation at the first weight, y_1. Fig. 9 shows the response to a step input at the first weight. While the over-all accuracy of this method is probably not better than 2% the ease of obtaining results with the analog computer is an argument in favor of this method over the normal numerical methods.

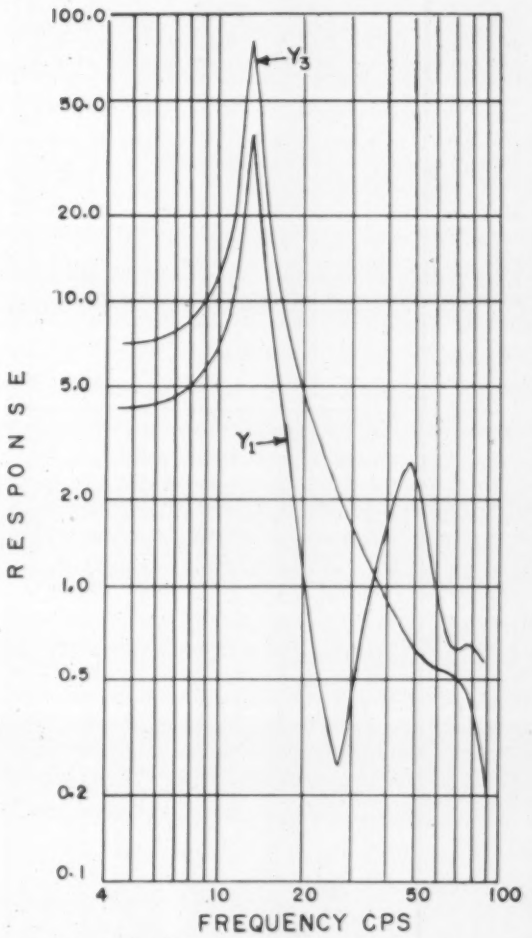


FIG. 8. **RESPONSE** of beam system of Fig. 4 with excitation at first weight (y_1).

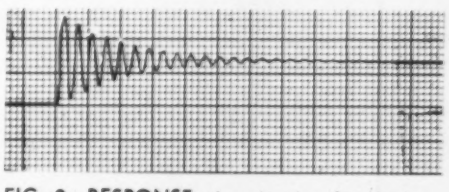


FIG. 9. **RESPONSE** at y_3 to step input at y_1.

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FIG. 1. TEST AND ANALYSIS of system design is accomplished by patching the problem into this Electronic Associates analog computer. The engineer observes the system response on a Brush direct-writing recorder.

By flying a plane in a zero-G trajectory, tests can be conducted on components and materials which will be used in space vehicles traveling beyond the gravitational force of the earth. Simulation assisted the design of the control system.

Simulation of

DESIGN of a control system for obtaining zero-gravity conditions in an aircraft is one of the problems studied in the laboratories of NASA in Cleveland. Control system designs are analyzed by running problems through an analog computer and recording the response on Brush direct-writing recorders. Systems parameters are varied and the change in response observed simultaneously, permitting a rapid approach to optimum conditions.

A manually controlled plane can be held at a zero-gravity condition only within certain broad tolerances. The NASA control system design will automatically keep the plane in zero acceleration more accurately and steadily than a pilot can.

The NASA design is a three-system three-axis control. The three parameters are pitch, yaw and thrust (roll of the plane is not of particular importance). Here, only the investigation and analysis of the thrust axis design shall be discussed; evaluation of pitch and yaw are similar.

Thrust

Design begins with a statement of the conditions of equilibrium at zero gravity. A series of equations relate airplane speed to an input of manifold pressure which will give thrust for a particular engine speed. The result of the mathematical calculations is the series of equations in Table 1. The differential equations in this case involve partials (the partial of thrust, for example, with respect to engine speed).

Fig. 2 shows a block diagram representation of the problem which is in a form convenient for analog computer solution. All variables are deviations from a steady-state point and, therefore, have a value of zero when the system is in equilibrium.

The first block represents a servo which receives the control error voltage and sets the regulator of engine manifold pressure (P_M). The transfer function of the servo is represented as a constant times a double lag (an overdamped second order system). The second block represents the manifold pressure regulator, the transfer function of which also is represented as a constant multiplied by a double lag.

The manifold pressure is multiplied by a constant and divided by the engine-propeller gear ratio to produce the torque absorbed by the propeller (Q_p), which is obtained by summation of the partials of torque with respect to airplane velocity ($\dot{S}_L$), propeller blade angle (β), and engine speed (N), quantities which are obtained from latter parts of the solution of the problem.

The difference in torque is divided by the propeller inertia and the reflected engine inertia to obtain the angular acceleration (α) of the propeller shaft. The acceleration is integrated with respect to time to obtain the shaft speed (N). Engine speed is fed into a representation of the engine speed governor which varies blade angle (β) to hold engine speed at a constant value. The transfer function of this controller is represented as an integrator times a lag. The partials of thrust with respect to airplane velocity, propeller blade angle, and engine speed are summed to produce the total thrust which is then compared with the drag obtained from airplane velocity, and the difference divided by the mass of the airplane to produce airplane acceleration ($\ddot{S}_L$). Two integrations produce airplane velocity and airplane displacement respectively.

The final objective of the system is to keep the airplane displacement (S_L) relative to a zero-gravity trajectory at zero. However, the loop cannot be closed around this variable without instability be-

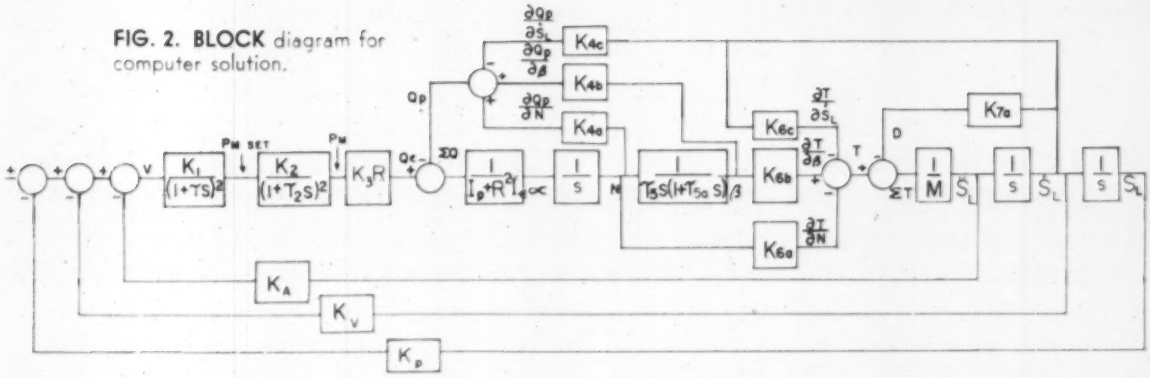


FIG. 2. BLOCK diagram for computer solution.

Zero-G Aircraft Control

EDWARD OTTO
and
THOMAS R. THORKELSON
NASA Lewis Research Center

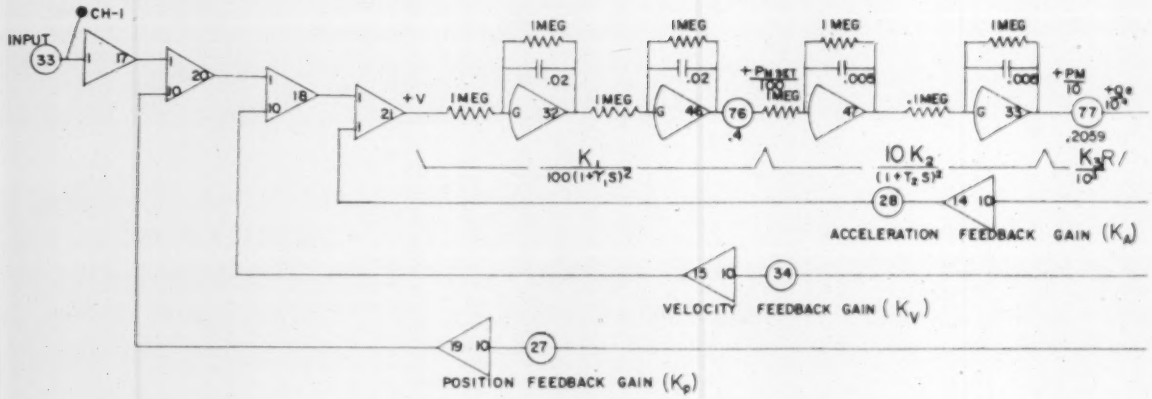
TABLE I—Equations and Constants

P_M = manifold pressure	K_1 = 40" Hg/volt
Q_e = engine torque	K_2 = 1" Hg/inch-Hg
Q_p = torque on propellor	K_3 = 72 ft-lbs/inch-Hg
R = gear ratio	R = 2.86
α = motor acceleration	$\frac{1}{I_p + R^2 I_e} = 0.0022$ rad/sec²/ft-lb
N = engine speed	
I_p = inertia of propellor	$K_{4a} = 150$ ft-lb/(rad/sec)
I_e = inertia of engine	$K_{4b} = 500$ ft-lb/degree
β = blade angle	$K_{4c} = 10$ ft-lb/(ft/sec)
T = thrust	$K_{6a} = 500$ lb/(rad/sec)
$\dot{S}_L$ = velocity of plane	$K_{6b} = 1000$ lb/degree
D = drag	$K_{6c} = 50$ lb/(ft/sec)
$\ddot{S}_L$ = acceleration of plane	$M = 1550$ lb-sec²/ft
S_L = position of plane	$K_{7a} = 100$ lb/(ft/sec)
τ = time constants	$\tau_1 = 0.02$ sec
K_A = acceleration feedback gain	$\tau_2 = 0.005$ sec
K_V = velocity feedback gain	$\tau_3 = 1$ sec
K_p = position feedback gain	$\tau_{5a} = 0.1$ sec
	s = differential operator d/dt

$\partial T/\partial N = K_{6a}N$	How thrust depends on engine speed
$\partial T/\partial \beta = K_{6b}\beta$	How thrust depends on blade angle
$\partial T/\partial \dot{S}_L = K_{6c}\dot{S}_L$	How thrust depends on plane velocity
$\frac{\partial T}{\partial N} + \frac{\partial T}{\partial \beta} - \frac{\partial T}{\partial \dot{S}_L} = T$	Total thrust is sum of partials of thrusts
$T - D = \Sigma T$	Thrust minus drag is effective thrust
$\Sigma T/M = \ddot{S}_L$	Force = mass times acceleration
$\dot{S}_L/\ddot{S}_L = 1/s$	Velocity is integral of acceleration
$S_L/\dot{S}_L = 1/s$	Displacement is the integral of velocity

$D = \dot{S}_L K_{7a}$	Drag depends on velocity
$\partial Q_p/\partial \dot{S}_L = \dot{S}_L K_{4c}$	How prop torque depends on plane velocity
$\frac{P_M \text{ SET}}{\text{VOLTS}} = \frac{K_1}{(1+\tau_1 s)^2}$	Error signal (volts) sets manifold-pressure regulator (P_M SET)
$\frac{P_M}{P_M \text{ SET}} = \frac{K_2}{(1+\tau_2 s)^2}$	Reaction of manifold pressure (P_M) to manifold-pressure regulator (P_M SET)
$\frac{Q_e}{P_M} = K_3 R$	Torque output of engine (Q_e) equals manifold pressure times a constant times engine-propeller gear ratio.
$Q_e - Q_p = \Sigma Q$	Difference between engine torque and propeller torque = torque available for accelerating prop.
$\frac{\alpha}{\Sigma Q} = \frac{1}{I_p + R^2 I_e}$	Angular acceleration of propeller shaft (α) = difference in torque (ΣQ) divided by sum of inertias of propeller and engine.
$\frac{N}{\alpha} = \frac{1}{s}$	Relation of engine speed (N) and acceleration (α): Speed = $\int$ Acceleration
$\frac{\beta}{N} = \frac{1}{\tau_{5a}(1+\tau_{5a}s)}$	Relation of blade angle to engine speed
$\partial Q_p/\partial \beta = \beta K_{4b}$	How prop torque depends on blade angle.
$\partial Q_p/\partial N = NK_{4a}$	How prop torque depends on engine-speed
$Q_p = \frac{\partial Q_p}{\partial N} + \frac{\partial Q_p}{\partial \beta} + \frac{\partial Q_p}{\partial \dot{S}_L}$	Prop torque is sum of partials of torque

FIG. 3. THRUST-AXIS automatic control system. Pickoff points indicate parameters recorded on the oscillograph. These include: Channel 1—Step Input; Channel 2—Engine Speed (N); Channel 3—Blade Angle (β); Channel 4—Acceleration of Plane ($\ddot{S}_L$); Channel 5—Velocity of Plane ($\dot{S}_L$); Channel 6—position of plane (S_L). Any of the other parameters may be recorded to check performance.



cause of the phase shifts due to the time integrations. It is therefore necessary to close the inner loops around airplane velocity and acceleration. The computer solution indicates the gains necessary in each feedback loop to optimize the response. This information allows the proper selection of accelerometers, controllers and servos to construct a satisfactory system.

Constants

In calculating constants the velocity of the aircraft at a particular time must be taken into consideration. When constants are initially calculated, velocity is assumed to be constant. For example, the velocity in the entire zero-G trajectory ranges from 150 ft/sec to 600 ft/sec. A constant velocity of 300 ft/sec is assumed and the behavior of the system studied. Eventually, instead of a constant, velocity will be a variable feedback voltage within the system.

Scaling

Amplitude Scaling

One of the more complex steps in setting up analog computor problems involves proper scaling. The value of a parameter such as torque may go up to 600 ft-lb (600 volts) at a particular point in the zero-G trajectory. Since output is represented by voltage in the computer, there must be a limit in voltage and the limit on the computer is plus or minus 100 volts. At no point in the problem can a voltage appear which exceeds this limit.

It is therefore necessary to scale the entire problem and make certain that nothing will exceed 100 volts. Should one point come out to be 600 ft-lb (600-volts) the problem will be scaled so that the voltage which appears at that point will not be Q (torque) but Q divided by a constant, for example 100. Now it appears as Q/100, or 6. This is a voltage which is tolerable in the computer.

Frequency Scaling

A particular maneuver may be executed in 1/100 of a second. A response which must be monitored will be fairly damped out in this short time. In order to record this response, time must be scaled. The computer can be set up so that one second of real time is represented by 10 or 100 seconds; the 1/100-second response can be stretched out to 1 or 10 seconds and recorded easily.

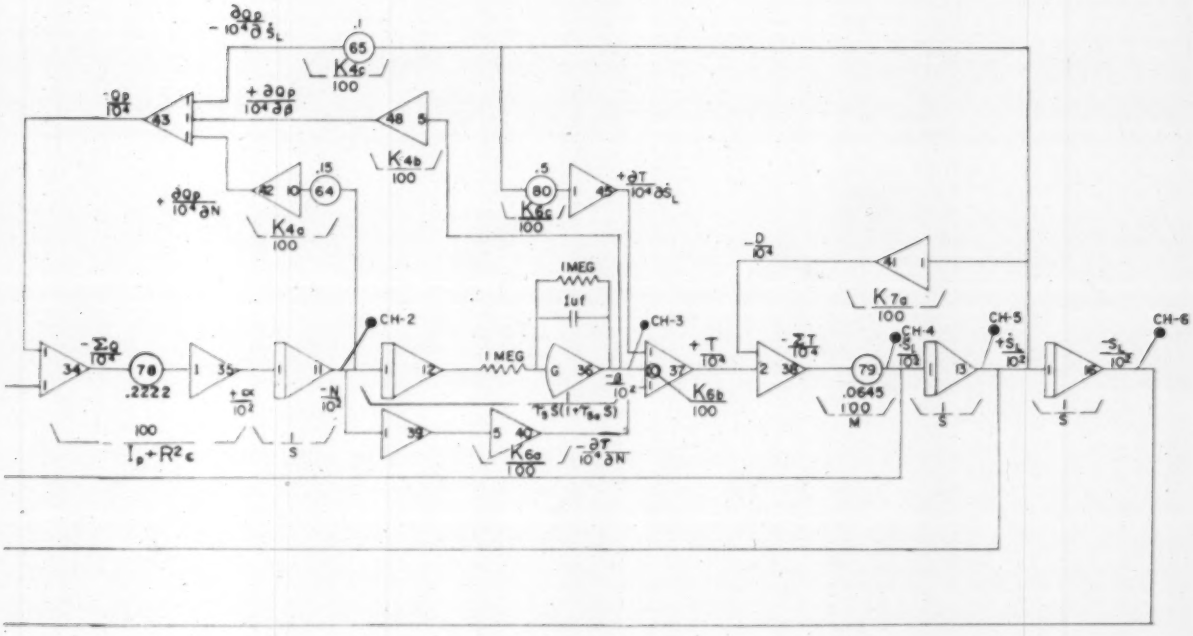
In the zero-gravity control system, time scaling had to be included in the pitch control system because time constants in the order of 0.005 second were encountered. In order to set time constants (real time) such as these into the network, gains of 10,000 would have to be used. It is not practical to put in such high gains in the system because the signal-to-noise ratio would be too low.

In the final problem it is necessary to tie the three loops or systems together. All systems must be matched to the same time scale before they can be tied in together. The practical approach is to scale all three down to the smallest time scale.

Patching

After the problem is scaled in time and in amplitude, diagrams are drawn putting in the various gains calculated and the computer is patched in.

Step inputs are impressed in the computer and the output recorded on direct-writing oscillographs. With each step input the gain feedbacks are changed and it is determined what gains can be



achieved and a fairly stable condition still maintained. If with a particular gain the response is slow, the gain is increased. Gain can be increased as long as stability is maintained. This process is repeated with each loop until all the loops are closed or until optimum response and stability are obtained. With all the loops closed, the system becomes a single unit with a single transfer function and a definite frequency response.

Frequency Response

Frequency response is obtained in the final system by viewing an oscilloscope. A sine wave is impressed on the input and the output observed. Test frequency ranges from 0.01 to 10 cps. Frequency-response tests performed on the open loop also aid in determining what gain can be inserted in feedlock loops.

A digital voltmeter is used to obtain precise reading of feedback gain setting. The digital voltmeter also is used to measure any steady-state conditions in the problem.

Typical pickoffs recorded on the Brush direct-writing oscillograph include: step input and deviations in acceleration, engine speed, blade angle, velocity of airplane, position of airplane, and thrust (Fig. 4).

Analysis

The purpose of the whole experiment is to determine if the systems will work, without buying expensive equipment at the beginning to test the design. The analysis obtained from the analog computer determines whether a feedback of five, or ten, or twenty is required. The success of the final design depends on the original analysis of the system.

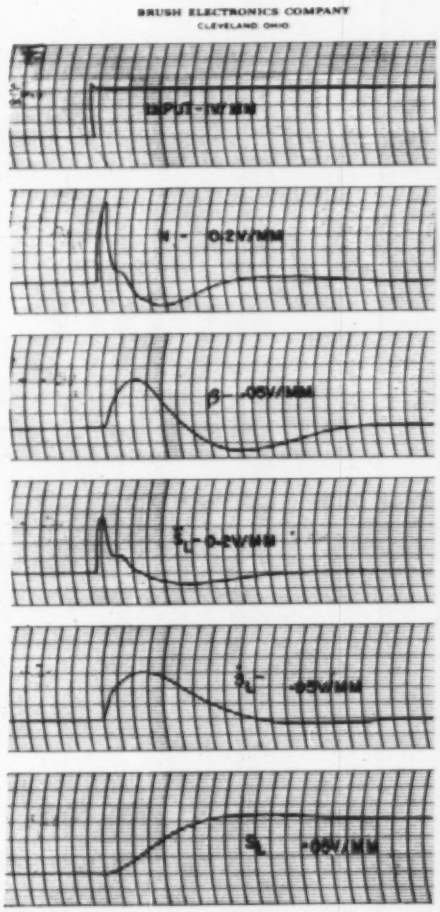
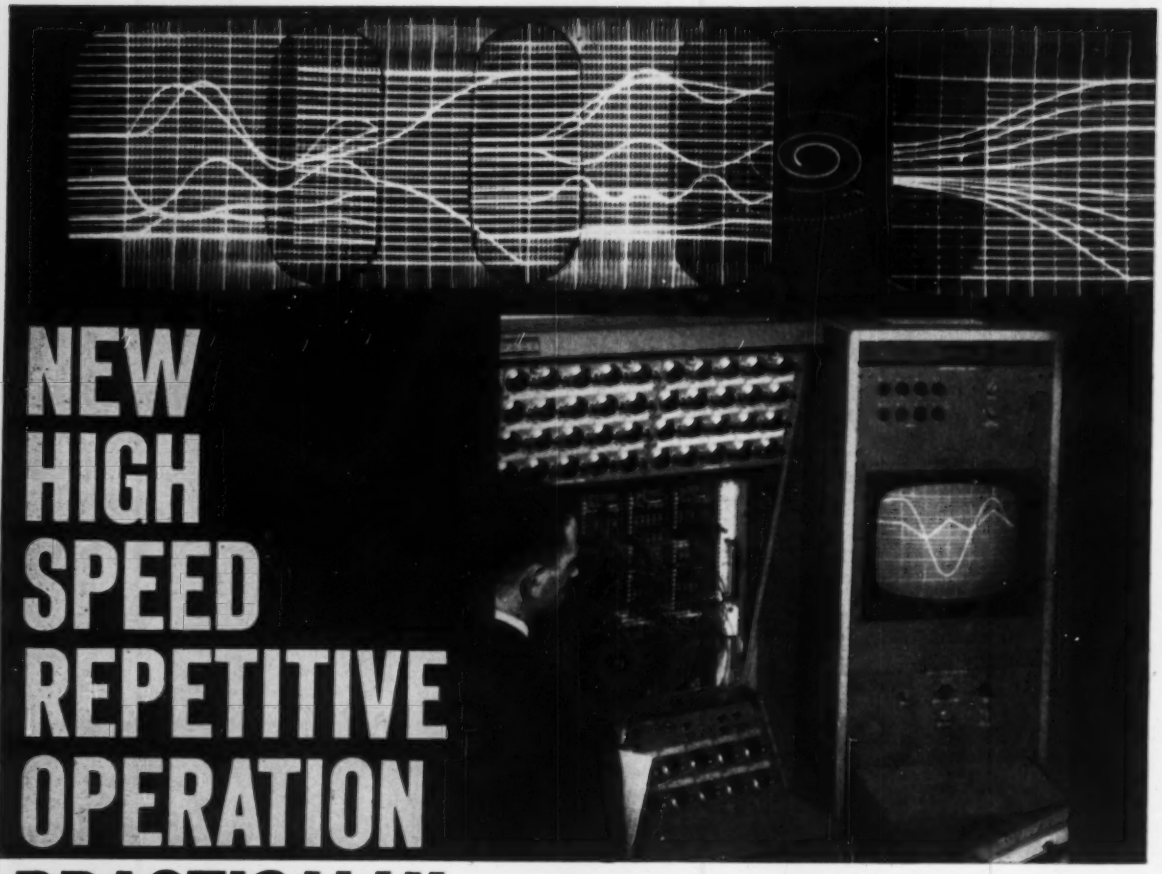


FIG. 4. A SET (six channels listed in Fig. 3) of oscillographic traces obtained from the analog computer.



NEW HIGH SPEED REPETITIVE OPERATION

DRASTICALLY CUTS ANALOG COMPUTATION TIME

The new EAI high speed repetitive operation system is ideally suited to systems design work because it produces solution repetition rates of 10 to 50 per second with *no loss of real time accuracy.* Used with Electronic Associates, Inc. Model 231R analog computer, it provides instantaneous change from real time operation to high speed repetitive operation by a single control . . . requires no re-patching . . . allows real time recording of selected solutions.

This newly developed system for PACE® analog computers can be used as a highly accurate and extremely versatile method for solving a variety of computational problems with greater speed and precision. It is an especially useful engineering tool for design problems involving simulation of servomechanisms, optimization of systems, solution of boundary value problems and mathematical 'model building'. High speed repetitive rates insure rapid approximation of optimum system parameters for control systems and determination of stability regions.

Outstanding features of the EAI high speed repetitive operation system include—

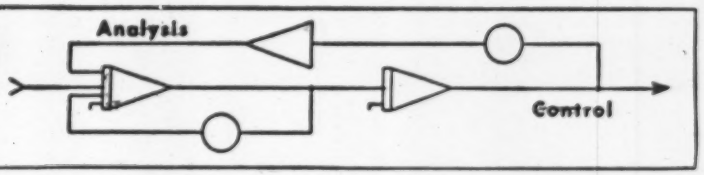
- **solution repetition rates of 10 to 50 solutions per second**
- **precision crystal oscillator control of display unit timing**
- **computer repetitive rate remotely slaved to precision crystal oscillator**
- **switched control of compute time with continuous control between steps**
- **electronically generated display grid . . . constant for repetitive rates**
- **simultaneous display of up to eight variables**

For complete details write for Bulletin AC-6034 describing the new EAI high speed repetitive operation system.

EAI ELECTRONIC ASSOCIATES, INC. *Long Branch, New Jersey*

CIRCLE 86 ON READER-SERVICE CARD

The SIMULATION COUNCIL Newsletter



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Bits

Still trying to catch up, so there will be more News (and less later) in this *Newsletter*. We find it necessary this month to adhere even more closely than usual to our policy of trying to inform our readers as to who where is doing what about which, rather than giving details of the technical presentations at the various Simulation Council meetings. So when the material covered has been treated —no matter how badly—in this *Newsletter* previously (as is the case with some of the papers presented at meetings covered this month) or has been published and is available elsewhere (as in the case with most of this month's papers) we will only give enough information in these columns to help you judge whether you wish to pursue the matter further—and if so, how to start.

With this justification, which we fervently hope the aggrieved authors will accept, we give you under **Pieces** what remains of the following papers which, as originally presented, ranged from worthwhile to excellent:

Jim Fenwick, "On the use of Simulation Techniques in Liquid Rocket Engine Development"

P. R. Dahl, "Simulation Aspects of Nuclear Ramjet Controls"

Richard J. Bohl, "Simulation of Nuclear Rocket Engine Dynamics"

A. C. Robinson, "Measurement of Stochastic Properties Using Analog Equipment"

John Munson, "Optimization by Random Search"

R. J. McGrath, "Adaptive Systems with Random Inputs"

Joe Thie, "Investigation of Random Processes in Reactors"

James Monsma, "Dimensional Tolerance Simulation"

Pieces

WESTERN S/C MEETING OF 10 MARCH

About ninety representatives of thirty-some odd (and some not-so-odd) organizations gathered at North American Aviation-Canoga Park (in California, near Los Angeles) on 10 March:

First on the program was a rather hurried trip through the NAA computing facility. We are indebted to Robert French of NAA for information concerning the Rocketdyne analog installation:

Computer	Amplifiers	Electronic Multipliers	Diode Function Generators
Beckman/Berkeley—1032	30	10	0
Beckman/Berkeley—1032	50	20	5
Beckman/Berkeley—1132	60	18	5
Beckman/Berkeley—1132	60	18	5
Electronic Assoc./Pace-16-131-R	60	10 (Dual Channel)	6

Additional equipment includes eight servo multipliers. This installation is unusual in the ratio of electronic multipliers to servo multipliers.

There is also an impressive installation of digital equipment which involves a data-processing system called, we don't know how appropriately, Idiot II. To understand the basic functions of this system see Fig. 1.

Of interest to some of us was a high-speed microwave link between the Canoga Park and Los Angeles computer labs of NAA.

This equipment consists of similar sets of Collins Radio transmitting and receiving equipment, Pacific Telephone and Telegraph modulating and demodulating equipment, and IBM

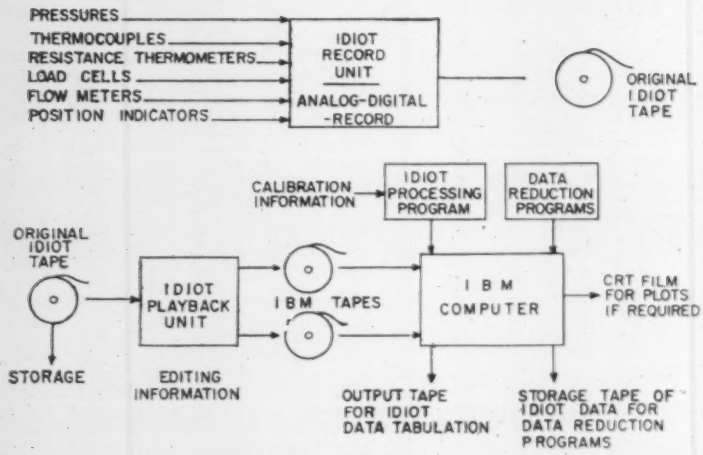

FIG. 1. IDIOT II System.

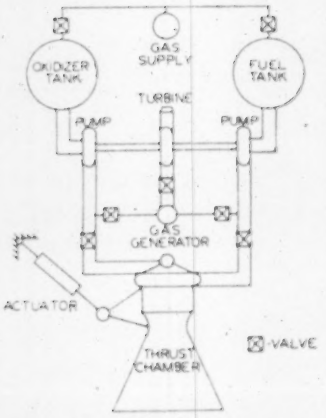

FIG. 2. PUMP-FED bipropellant liquid rocket engine.

tape and card equipment.

The plants are only 25 air miles apart, but because of line-of-sight considerations a relay station on Oat Mountain is used, making the microwave link, which is capable of handling about 120,000 bits per second, about 40 miles long.

There are complete computer facilities at each plant; the microwave link is simply a "tie line" to equalize the load.

After this brief look at the grandeur of NAA computing hardware we hurried to the chartered buses—private cars not allowed (no level space in the mountains)—that took us to the NAA test facilities in the Santa Susana mountains.*

Whereas some of us had expected "just" test pits, the installation was complete with offices, cafeteria, and a sizeable and comfortable meeting place where the Western Simulation Council technical session was held.

Fenwick on Rocket Engine Control

The first talk, by *Jim Fenwick* (NAA-Rocketdyne, Canoga Park, Calif.) was based on a paper "Simulation Testing of Rocket Engine Control Components" (an ASME publication, Paper No. 60-AV-24), of which Jim says "additional copies are available and will be mailed on request."

"Twenty-five years ago rocket engines were considered a curiosity with little practical application," the paper states. "Few people knew or cared about rocketry. Today rocketry is represented in this country by a multimillion-dollar industry, vital not only to the immediate safety of our country but also to our prestige as one of the world's greatest powers. It has been pointed out that the rocket industry has three characteristics which put it in a class by itself:

"1. A rapidly advancing state-of-the-art in the design of major components.

"2. Short runs of low-rate production.

"3. Accelerated programs which necessitate concurrent research, development, and production.

"These characteristics, and the feeling that we are in international competition, are conducive to the use of promising though unproven concepts and techniques in all phases of this industry. The fruits of many of these new concepts and techniques are sure to be reaped as significant technological advances in many fields other than rocketry.

"One of the most promising new techniques employs analog-computer equipment and appropriate transducers to permit control components to be run closed-loop in a simulated engine environment prior to actual use on an engine. The analog computer and transducers simulate the necessary engine dynamic effects, providing more extensive component checkout than bench tests. This extensive checkout, in turn, greatly improves the probability of component success on the first 'live' engine test.

"The use of simulation suggested in this paper exploits simulation flexibility by utilizing a general-purpose computer as the heart of the simulator and suggests a general-purpose complement of transducers, adaptable to the testing of many varied controls.

"The discussion of rocket-engine control-component testing by simulation includes a description of a pump-fed liquid-rocket engine, the typical engine-development cycle, the simulation approach, and several cases where it has been used, and a short discussion of typical simulation requirements and the transducer problem.

"To understand the ramifications of simulation testing in the rocket-engine industry, it is necessary first to understand the problems and complexity of the rocket engine itself. A simplified rocket-engine schematic is shown in Fig. 2 with the position of possible control components indicated. This is a pump-fed liquid bipropellant rocket engine, the most versatile rocket engine being made today.

"Two storage tanks under low pressure supply propellant to the turbopumps. The pumps raise the pressure of the propellants so that they can be forced through the thrust-chamber injector at a high rate. Combustion occurs in the thrust chamber, and the resultant hot gases flow through the chamber nozzle and out the bell. Energy is supplied to the turbopump by either burning a small amount of propellant from the main flows (a so-called 'bootstrap' system) or by using auxiliary propellants contained in small pressurized tanks.

"The major components of the engine are:

"1. The tanks, thrust mount, and

*Biggest stack-o-rocks we ever saw—we felt like ants in a sandpile!

main propellant ducting;

"2. The turbopump, turbine, and gas generator;

"3. The thrust chamber and injector.

"These are generally large, expensive items and, if anything goes wrong in a test, their replacement represents the expenditure of considerable money and time.

"The control components are usually neither as expensive nor as cumbersome and difficult to replace as are the major components. They are used in starting and stopping the engine, eliminating the effects of missile acceleration, providing minimum burnout weight by emptying the tanks simultaneously, and controlling engine performance by maintaining constant thrust-chamber pressure or turbine power.

"Although each type of engine has its own explosive personality* they are all similar in that they produce extreme power from the continuous combustion of great quantities of naturally unstable propellants under high pressure. In controlling these giants, we cannot trust man's indecisiveness nor can we tolerate his slow reactions. The controls we use must, in every case, be fast and sure. They must be molded around each type of engine individually to obtain maximum performance and to minimize the all-too-apparent hazards.

"The simulator describes the engine environment in as much detail as is deemed necessary for an adequate closed-loop test. The effect of engine start, mainstage, and shutdown operation on the component can be observed under laboratory conditions. If the component operation is not satisfactory the component is redesigned prior to costly engine operation. If the component operates satisfactorily with the simulator, it will have a good chance of successful closed-loop operation with an engine."

This principle holds, even if the component is a human**. "Scott Crossfield, an able and experienced test pilot, found it necessary to fly hundreds of hours in a North American Aviation simulation of the X-15 before going aloft. That simulation was a cockpit, a movie projector, and an analog computer.

*Wish I'd said that!—Ed.

**Though in this case, due to the complexity of changing the design, he is "retrained."

"The use of a simulator for component checkout is certainly the most important phase of its operation, since the reduction of hazardous testing represents an obvious saving in money and time. But its use should not be restricted to this operation since, once built, any further use represents only the expenditure of manpower costs, a negligible item.*

Simulation should be investigated when any of the following signs is apparent:

"1. A very few expensive complex systems are to be produced.

"2. System performance depends on a critical but complex control component.**

"3. Short schedules necessitate full component development prior to system testing.

"4. Reliability testing is necessary on minor components, but the tests on the full system are hazardous and expensive.

"5. Environmental conditions may be critical to a component, but it is not practical to subject the full system to these conditions."

If such signs, or your natural interest, indicate further study of this matter, we suggest that you write for a copy of the ASME paper and check these references:

1 "Transition from Prototype to Production," by S. K. Hoffman, ARS Semi-Annual Meeting, Los Angeles, California, June, 1958.

2 "A Flexible Turbojet Engine Simulator," by C. R. Heising, Second National Simulation Council Meeting, Houston, Tex., April, 1957.

3 "Mechanical Analog 'Stands In' for Steam Turbine," by S. Jacobs and D. L. Rexford, Control Engineering, September, 1959, pp. 190-191.

4 "Simulation Cuts Flight Tests of New Autopilot," by L. T. Prince, Control Engineering, September, 1959, pp. 194-195.

5 "Perturbation Analysis of Low Frequency Rocket Engine System Dynamics on an Analog Computer," by B. N. Smith, Jet Propulsion, January, 1956.

6 "On Techniques for the Analysis, Synthesis and Simulation of Liquid Bi-Propellant Rocket Engine Systems," by G. L. Wade, MS Thesis in Engineering, University of California, Los Angeles, 1959.

Dahl on Ramjet Control

The next talk was "Simulation Aspects of Nuclear Ramjet Controls" by *P. R. Dahl* (Marquardt Corporation, Van Nuys, Calif.). So far as we know this paper has not been published elsewhere. The first part, "Ramjet Characteristics," theoretically does not concern us because simulation of these characteristics is not discussed.

*In spite of the fact that I keep trying to talk the boss into making mine non-negligible! Ed.

**Like a Wife?

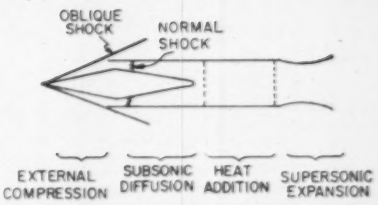

FIG. 3. RAMJET ENGINE.

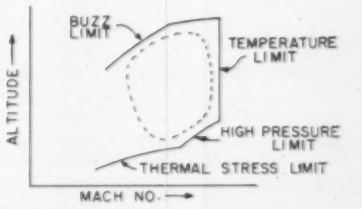

FIG. 4. ENGINE CHARACTERISTICS.

Mr. Dahl did, however, present an erudite treatment of the simulation of nuclear reactor dynamics. So what does your Ed. do? He gives you P. R. Dahl's introduction to Ramjets (because we found it interesting) and deletes his treatment of the simulation of the reactor (because it has been treated, retreated, and treated again—elsewhere).

So, according to Dahl, Fig. 3 shows the basic elements of a ramjet engine.

"The simple ramjet engine shown is limited to operation in the earth's atmosphere because it relies on inlet air for oxidizer in the case of the chemical ramjet, and for propellant in the case of the nuclear ramjet. Moreover it is limited to operation in a flight regime within which various engine variables are not exceeded. Fig. 4 shows the characteristic limits on a ramjet which define a flight envelope.

Buzz is caused by the engine expelling the normal shock from the inlet. A relaxation oscillation in the engine flow and normal shock positive occurs which will damage the engine structure if buzz persists.

Fuel-to-air ratio, if it exceeds rich or lean limits, will cause engine blowout.

Free stream total temperature increases with Mach number. Structural or reactor core material temperature limits will impose a limit.

The engine structure will limit the maximum pressure allowable in the engine. Stagnation pressure and pressure recovery, a function of Mach number and engine design, will define this limit in the flight envelope.

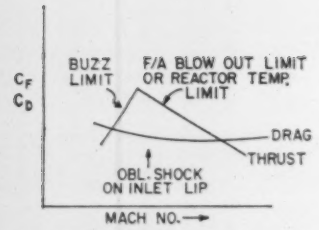

FIG. 5. THRUST and drag characteristics.

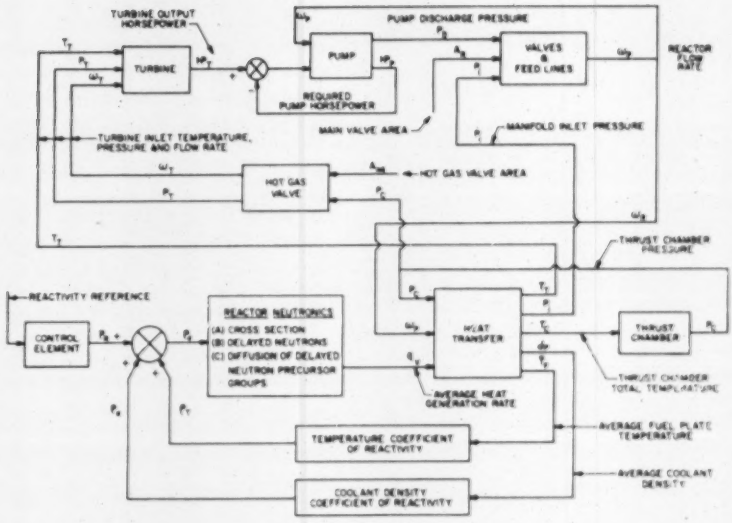

FIG. 6. ELEMENTS of nuclear rocket engine.

Thermal Stress

The heat exchanger used in a nuclear ramjet relies on large temperature gradients for efficient heat transfer. Temperature gradient, however, is related directly to thermal stress which cannot exceed the strength limitations of the heat exchanger material.

Thrust Characteristics

Engine thrust and vehicle drag are shown in Fig. 5.

"The limiting quantities discussed are indicated on the figure. It is apparent that vehicle flight is limited to the Mach number range within the closed triangular area.

"The quantities indicated must be controlled to insure their being held within defined limits. In most cases only one independent variable at a time is at the control engineer's disposal to hold all of the mentioned dependent variables within their design limits. Thus it is necessary to 'switch,' 'auctioneer,' or 'override' the control system from one input-controlling variable to another."

Superimpose on this all the complexities of reactor control, and you will get an idea of the complexity of the problem solved by Marquardt through Simulation.

Bohl on Rocket Engines

Again, having described the application, we refer you to the author for details. As his complete notes were in reproducible form (ditto), he will probably be glad to send you a copy.

The third talk—by *Dick Bohl* (Rocketdyne Div., North American Aviation, Canoga Park)—was based on notes* prepared for the occasion in order to emphasize the analog-simulation aspect of the study. However, the material was essentially that covered in "Dynamic Analysis of a Nuclear Rocket Engine System" published in the American Rocket Society's *Journal* for November, 1959.

In his paper a technique for simulation of a nuclear rocket engine system is outlined. The nuclear rocket engine (see Fig. 6) is similar to the chemical rocket engine with one major exception—a nuclear reactor is substituted for the combustion process of the chemical engine. Characteristic differential-equations describing the nuclear engine system dynamics are solved on an electronic differential analyzer.

"Simulation is necessary for the economic design of nuclear rocket engines with adequate, safe and reliable controls," Dick said, and certainly most people will agree. However, we will not report the details of his simulation here because:

1. They're available elsewhere;
2. Even if *you* have a similar problem the details would differ.

However, you can get a good idea of the nature and scope of the problem treated by looking at the block diagram of the system as shown in Fig. 6.

Following the third and last talk of the technical session, we adjourned for lunch, then all piled into the buses to go witness some test firings. At the first stop the observation station must have been about half a mile from the test stand, which prompted someone to voice a sentiment that I believe most of us felt: "Gosh, is this as close as we can get?"

"Oh, I believe you'll find it close enough," said our guide—and how right he was!

We heard the last few seconds of the countdown and then the fun began! But let my colleague Allan Wilson, who apparently wasn't so awed* as ye Ed and Suzy, tell about it:

"In the afternoon, we witnessed two very dramatic test firings. The first was a full-scale (5,000 mile) Atlas engine run. From a distance we watched the last minutes of the countdown and prompt ignition of the Verniers and the three main engines. All engines fired at full power for about three minutes. Boosters then cut out and the other engines fired for another two minutes. It appeared to us that the test was a complete success.

"The second test was a single sustainer engine test viewed at much closer range—about 700 feet. It was mounted horizontally, with the business end pointed almost directly toward us. As the noise level was close** to the threshold of pain, and as thermal radiation was distinctly noticeable, it was apparent that closer observation would have required protective gear.***

"Shock diamonds were evident in the flame, and as the fuel-to-LOX ratio was changed we saw—and felt in our stomachs—a definite change in the flame pattern.

"I left the test firings with a distinct increase in respect for the Mercury Astronauts who will have the courage to sit on top of that raging inferno and blast off into space!"

A very unusual Simulation Council meeting!

---

*Also ditto—or should we say "ditto²."

*i.e., nearly knocked flat!

**Which side?

***Your Ed would have preferred a fallout shelter to fall out in!

MIDWESTERN SIMULATION COUNCIL MEETING OF 14 MARCH ON RANDOM PROCESS STUDIES

About 44 people attended the 14 March meeting of the Midwestern SC held in Wisconsin Center of the University of Wisconsin, Madison. Subject was "Random Process Studies by Analog and Digital Methods."

Robinson on Stochastic Properties

The first talk was "Measurement of Stochastic Properties Using Analog Computing Equipment" by *A. C. Robinson* (Wright Air Development Center, Dayton, Ohio). The following are Robie's notes. After you've read them and studied Figs. 7 and 8 you will know as much (or probably more) about his presentation as we do.

THEOREM 1. Determination of Mean Value

Let $x(t)$ be a stationary, ergodic random process of mean M. Let $y(t)$ be another random process defined by $y(t) = x(t) - M$. If $y(t)$ has a continuous power spectrum (no periodic components) then a consistent and convergent estimate of M is given by

$$M_T = \frac{1}{T}\int_0^T x(t)\,dt \qquad (1)$$

Furthermore, the ratio of the variance of the estimate to the variance of $y(t)$ is given by

$$\frac{\partial_M^2}{\partial_y^2} = \frac{2}{T}\int_0^T \left(1 - \frac{\tau}{T}\right) \rho_y(\tau)\,d\tau \qquad (2)$$

where ∂_M^2 is the variance of the estimate, ∂_y^2 is the variance in $y(t)$, and $\rho_y(\tau)$ is the normalized autocorrelation function of $y(t)$. Also, the limit of the integral of (2) exists as T becomes infinite.

THEOREM 2. Determination of the Autocorrelation

Consider a random process $x(t)$ which satisfies all the conditions of Theorem 1, and in addition is Gaussian. Then a convergent and consistent estimate of the autocorrelation of $x(t)$ is given by

$$\phi_T(\tau) = \frac{1}{T}\int_0^T x(t)\,x(t+\tau)\,d\tau \qquad (3)$$

and the variance of this estimate obeys the relation

$$\sigma^2 \leq \frac{4}{T}\int_0^\infty \Phi_y^2(\tau)\,d\tau + \frac{8M^2}{T}\int_0^\infty |\Phi_y(\tau)|\,d\tau$$

where $\Phi_y(\tau)$ is the autocorrelation of $y(t)$.

Anyway, it's an interesting and important technique. If you have use for it we are sure a letter to Robie will get you the necessary details*.

Munson and Rubin on Random Search Optimization

The second talk on the program was based on a paper "Optimization by Random Search on the Analog Computer" by *John K. Munson* (Engineering Services Div., DuPont, Wilmington, Del.) and *Arthur Rubin* (Electronic Associates, Inc., Princeton, N.J.), which was originally given at the National Simulation Conference in Dallas in October of 1958.

"Recent years," the paper points out, "Have seen increased emphasis on optimum design and operation and military weapons systems, physical and chemical processing systems, and business systems. In general such systems can be designed and operated under many different sets of conditions. It is the purpose of an optimization study to determine the best combination of such conditions within restraints imposed by economy, physical size, and other limitations of a system or surroundings.

"An investigation of a typical system includes the following steps:

a. Describe system operation by a set of equations obtained theoretically or through study of an existing pilot unit.

b. Specify restraints on the variable system parameters.

c. Express the characteristics to be optimized as a function of all significant system variables and define the 'optimum' value.

d. Devise a method of choosing combinations of system parameters for evaluation which will allow selection of optimum conditions in an economical manner."

"For example, consider a chemical reactor which will operate under many combinations of temperature, pressure, catalyst activity, and reactant concentrations. Optimum design and operation of this reactor is defined as that combination of conditions which will supply the available market demand at the lowest operating cost. In order to find the optimum it is necessary to have available a model reactor or its mathematical equivalent. Restraints on the variables must be specified. For example, the maximum pressure allowed at any given temperature due to strength of materials or capabilities of auxiliary equipment such as pumps and blowers. An equation describing the operating cost as a function of the system variables must be written. A method of experimentation is necessary which will locate the area of optimum operation with an economical expenditure of time and effort.

"The traditional role of the analog computer in optimization studies has been to act as an electronic mechanization of a mathematical model of the system to be investigated. Design parameters and operating conditions can be easily changed and system operation determined quickly, economically, and safely. The model is run under many sets of operating conditions. The results of such a set of experiments can be analyzed by statistical regression techniques in order to point out the area of optimum operation. Also, linear programming techniques have been applied, where appropriate."

The paper describes an application of the analog computer which decreases the amount of statistical analysis and auxiliary calculation required. The high speed of the computer is utilized to evaluate many more combinations of operating variables than would otherwise be economically feasible.

The Random Search Method; Typical Circuitry, including random noise generators, comparison and storage circuits, and restraint limiters; applications and conclusions are considered in the paper, which is such an excellent treatment of so important a subject that if it hadn't already been published we would have tried to give it to you verbatim in the Newsletter. Under the circumstances we recommend that those interested in the technique request copies from the author and/or check these references:

1. *I. B. Pyne*, Linear Programming on an Electronic Analogue Computer, AIEE Transactions, 75, Part 1, p. 139-143, May, 1956.

*Mr. A. C. Robinson, Attn: WCLJY, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio.

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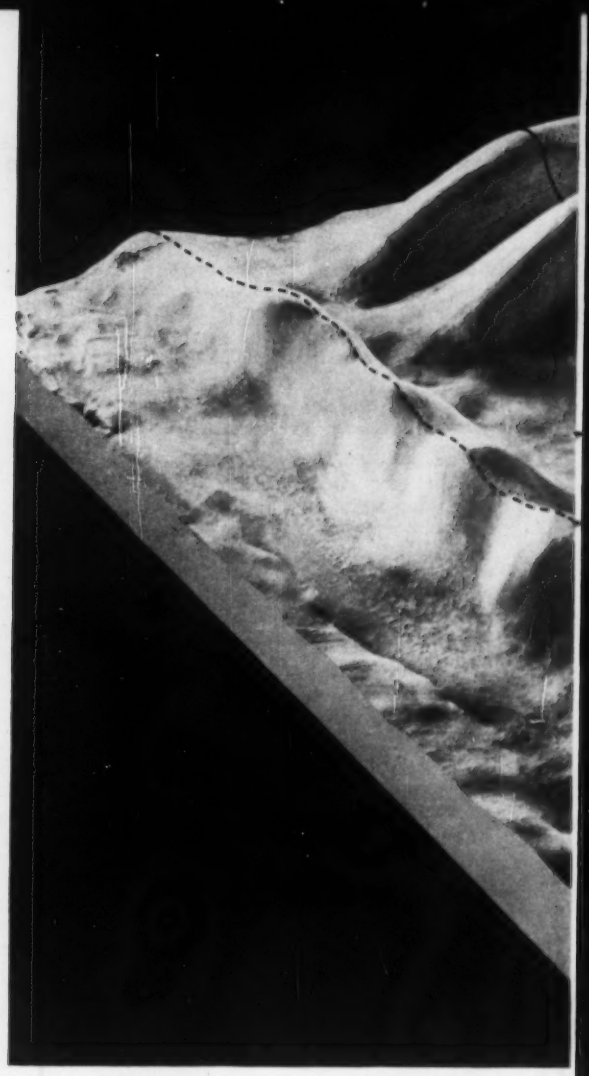


Whether your problems are dynamic or static, covering costs, design, or production control in: Operations Research, Chemical Kinetics, Aerodynamics, Structures, Astrophysics, or Hydrodynamics, DYSTAC computers can solve them faster, more accurately, and more economically than any other computer.

The reason is simple: DYSTAC is a new kind of computer. It combines the best features of both analog *and* digital machines.

Only DYSTAC by CSI incorporates high-speed repetitive operations with dynamic storage of analog data to an accuracy of 0.01% and with a time-base accuracy of ±0.5 microseconds.

DYSTAC provides unique time-sharing of computer components and high speed reiterations. These features make possible economic and rapid solution of complex problems that have required too many computer components, or too long a solution time, to be considered practical for either digital or analog machines. And you can expand the number of operational amplifiers by a flick of a switch which converts the precision Dynamic Memory units into Fixed and Summing Integrators.

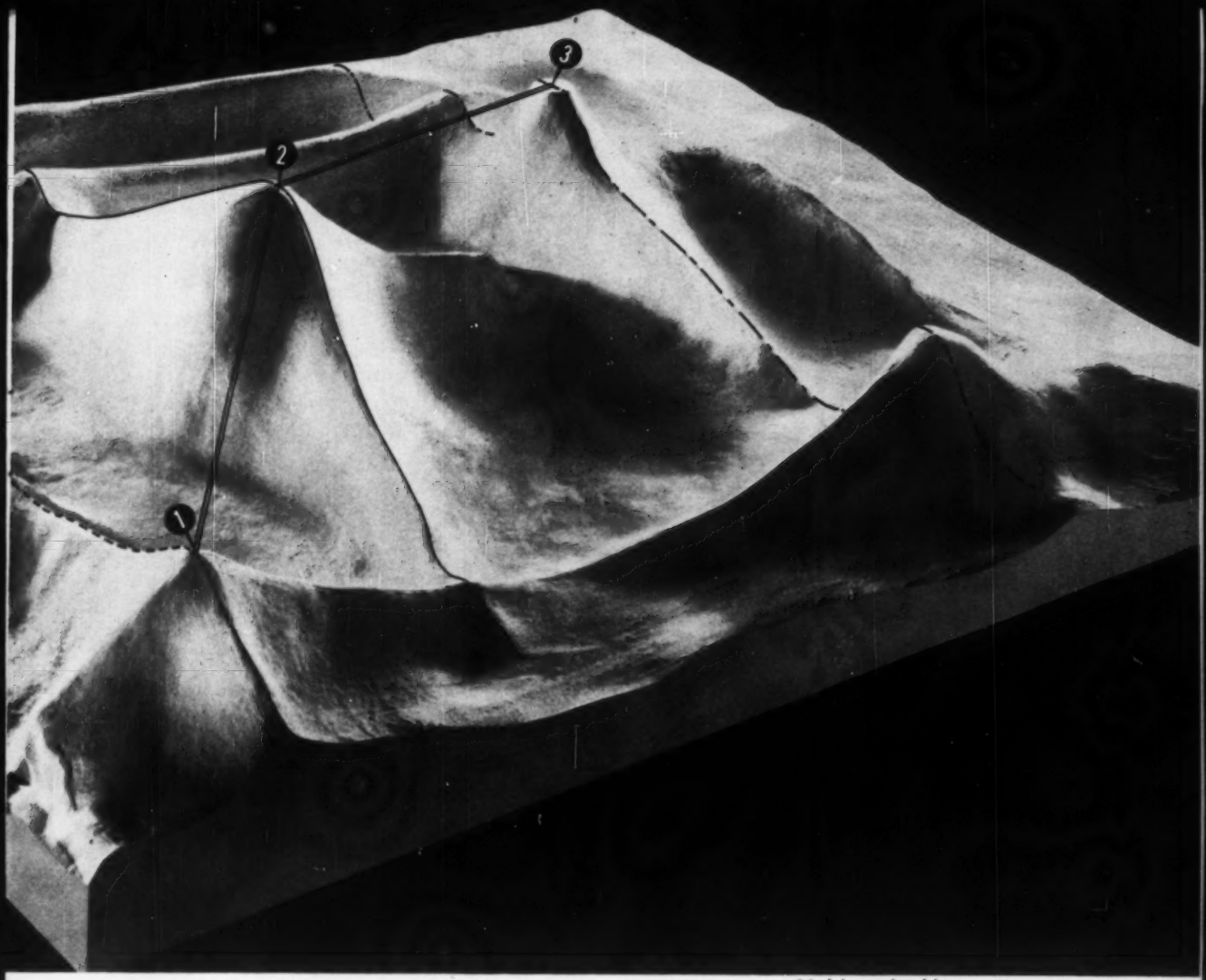
$\left(\frac{\delta a}{\delta t}\right)$ - - - - - - - This curve describes the design parameters for the entire process, with the maximum design factor occurring at point (1).

$\left(\frac{\delta b}{\delta t}\right)$ ——— This curve describes the profitability of the process. Note peak (2), where maximum profitability occurs.

$\left(\frac{\delta c}{\delta t}\right)$ - — - — - This curve shows the product quality variation. Maximum quality plateaus at point (3).

❶ ❷ ❸ ═══ Optimization for the entire process is achieved by operating along points (1), (2), (3).

CIRCLE 87 ON READER-SERVICE CARD



Model correlated by DYSTAC computer

60-SECOND SOLUTIONS OF EVEN THE MOST COMPLEX PROCESS PROBLEMS WITH DYSTAC

The problem of optimizing feed stocks and operating conditions in chemical kinetics problems has always defied continuous automatic solution. With any computer, other than DYSTAC, solutions require invalid oversimplifications. DYSTAC computers solve these problems by least-mean square procedures at *high speed* and with a *minimum of components*. Accuracies are held to ±0.05%. Send for complete 26-page report entitled *"Correlation and Optimization of Chemical Kinetics Models"*.

20-SECOND SOLUTIONS FOR THESE PROBLEMS

- multi-dimensional partial differentials (steady state or transient)
- sequential, successive solutions for algebraic matrices at 60 to 100 cps
- definite integral calculations
- multiple integrals and partial differential equations

...or any combination of these problems.

Write for complete details on how DYSTAC computers can work for you.

COMPUTER SYSTEMS, INC., Culver Road, Monmouth Junction, N. J. • DAvis 9-2351

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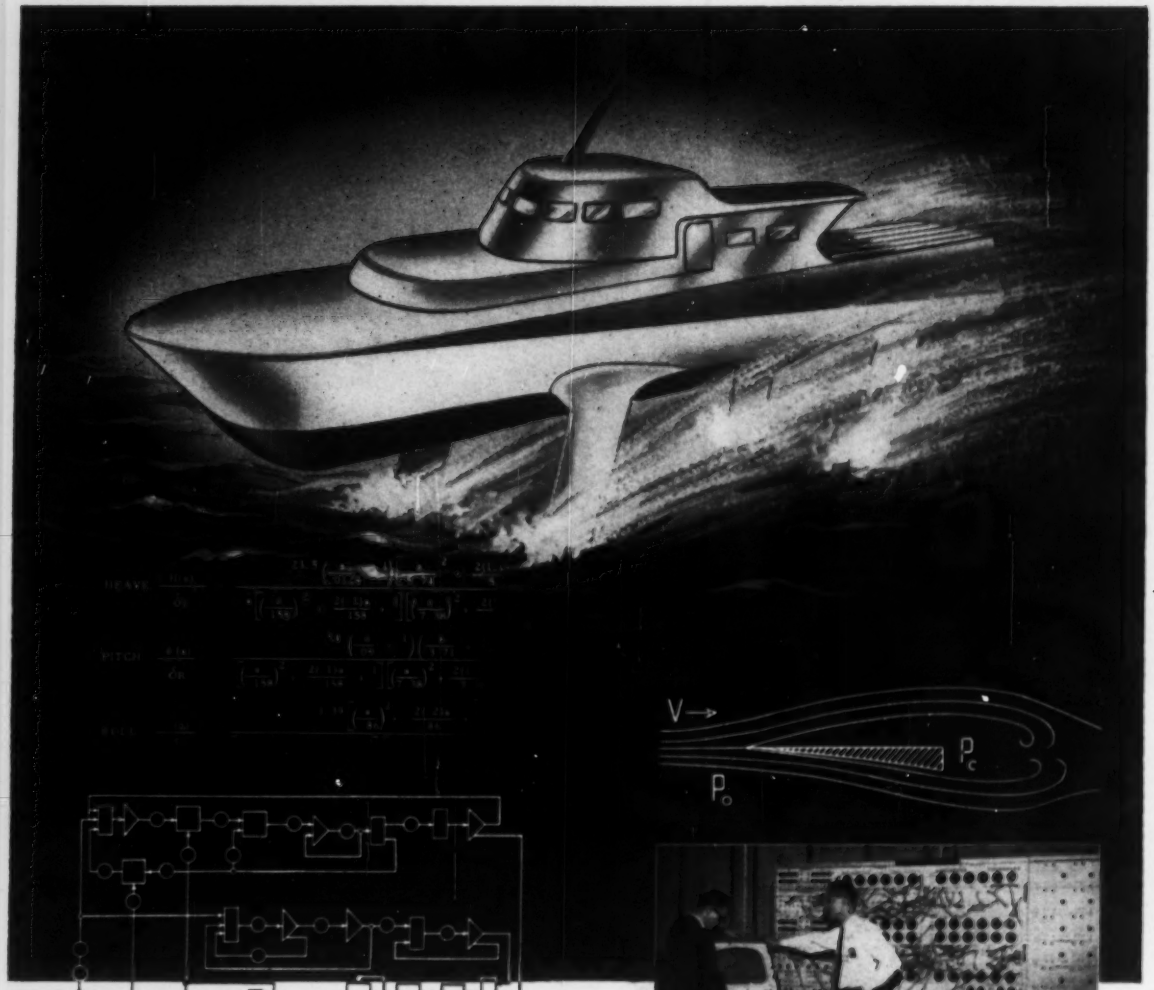

GPS COMPUTER AT HAMILTON STANDARD, BROADBROOK, CONN.

Simulation Studies of Hydrofoils at HAMILTON STANDARD ELECTRONICS

The Electronics Department of Hamilton Standard Division, United Aircraft Corporation is designing stabilization and control systems for hydrofoil craft. The GPS Statistical Analog Computer is the one being used in the system optimalization. The wealth of practical experience that Hamilton Standard Electronics has acquired in stabilization control of helicopters is being applied to the stability control problems of hydrofoil craft.

Dynamic characteristics as well as the performance of the CONTROL-HYDROFOIL system in the presence of random disturbances caused by complex wave motion over the full range of sea state conditions are being examined. Dynamic and probabalistic responses are generated simultaneously and directly on the GPS Statistical Analog Computer with a considerable savings in time and manpower.

Why not investigate the computation possibilities of the GPS Statistical Analog Computer in your research.

GPS Products. Compressed — time scale analog computers and high speed statistical computers

GPS INSTRUMENT CO., Inc.

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2. *J. D. Strong*, Optimizing With a Computer, *Automatic Control*, p. 16-19, June, 1956.

3. *R. R. Favreau* and *R. G. E. Franks*, Statistical Optimization, presented at the Second International Conference for Analog Computation, Strasbourg, September, 1958.

McGrath on Adaptive Systems

The third talk was "Adaptive Systems with Random Inputs" by *R. J. McGrath* (University of Wisconsin). We have nothing on this presentation but the author's own summary, as follows:

"Some of the problems which result when adaptive systems are subjected to random inputs were discussed. A system was described which used continuous parameter disturbance and correlation detection of the disturbing signal in some error measure. This result was fed into a parameter controller and adjusted that parameter to minimize the error measure. The parameter misadjustment could be caused by either an input process change or system parameter changes. Experimental results were shown for a simulation which adjusted two parameters simultaneously."

Dick writes that he and Professor Rideout are preparing a paper for the IRE-PGAC on the subject.

Thie on Reactor Noise Analysis

The fourth talk was based on a paper, "Statistical Analysis of Power-Reactor Noise" by *J. A. Thie* (Argonne National Laboratory, Lemont, Illinois) which was published in *Nucleonics* in October 1959 and describes an interesting technique for getting some use out of noise.

"The rate of fission in a reactor operating at a certain power level does not remain perfectly constant with time," states the author, "but fluctuates in a random way about an average value. This reactor "noise," because it stems from statistical fluctuations in reactivity inherent in the system (such as turbulent flow of the coolant), is present as an unavoidable condition in all reactors. However, there is a way to put reactor noise to some use—a frequency-spectrum analysis of the noise can provide, essentially "free-of-charge," some interesting information about reactor kinetic performance.

"Fourier transform methods already used to analyze the radar signals, light from twinkling stars, etc. permit one to determine the distribution of frequency components present in reactor power fluctuations. Once we have this frequency distribution, we can extract from it various kinds of information:

"• A recording of reactor flux fluctuations is all the experimental information needed to detect sharp resonances in reactor transfer functions. (For precise measurement of broad resonances, a knowledge of the approximate shape of the noise spectrum driving the reactor is helpful.)

"• In zero-power reactors noise analysis will give the neutron lifetime (1).

"• For other reactors the coefficients in the differential equations governing dynamic behavior can be obtained (2, 3).

"• A power spectrum derived from noise analysis together with a measured or calculated transfer function will yield information about the basic causes of reactor noise.

"• Continual monitoring of reactor noise could provide an additional safety check for the reactor operator. For instance, an analog computer might continuously analyze the fluctuations (see Fig.) and display the instantaneous power spectrum to the operator, who could check it for the appearance of resonances."

Power fluctuations, autocorrelation, analog simulation, power-spectrum analysis, and reactor stability are all treated in some detail in the *Nucleonics* article.

Monsma on Dimensional Tolerances

The fifth and last paper on the program was interesting and, for a Simulation Council meeting, unusual. It was interesting because of the importance of the subject treated, and unusual because it describes the use of a digital computer for simulation.*

The title of this excellent paper is "Dimensional Tolerance Simulation" by *James E. Monsma* (Applied Science Representative, IBM, Peoria, Ill.)

"Simulation does not make the strong claim in digital computing that it does in analog work," the author begins. "Much digital work is done in the area of data processing for business accounting and management. Even digital computing which is of a scientific or engineering nature is viewed as formula evaluation or number manipulation, rather than as a simulation of some physical situation.

"On the other hand, simulation is not new in digital computing. Some of the first applications were simulations in the field of nuclear physics. Recently there has been a renewed interest in simulation, and it is fast becoming a most important digital computing technique. Two of the most interesting and important recent simulations are:

"*The Business Game*—Simulation of an economic atmosphere. This technique offers the fields of business and economics their first real laboratory.

"*Job Shop Simulation*—This technique offers management a tool for better understanding of its business.

"One interesting fact about digital computer simulations is that almost without exception they employ random number techniques; even those which are basically deterministic in nature. Both types of simulation have stochastic elements. In business games sales are generally a random variable. In the job-shop simulator orders may be released to the shop randomly. The simulation I am going to talk about today, however, is stochastic by its very nature. It is a dimension tolerance simulator and lies on the border line between engineering design and manufacturing. I refer to it as the 'Tolerance Problem', since this is the way it was first brought to my attention a few years ago.

"The basic problem, I think, must be laid at the feet of manufacturing. By the very nature of the manufacturing process no two parts come out exactly alike. There are always slight variations.

"Since these variations can cause some problems in assembly, the manufacturer has persuaded the design engineer to prescribe tolerances to the dimension of the parts. If all parts are within tolerance, the assembly is expected to perform as required. So most design engineers have prescribed tolerances in such a

*Digital simulations per se are far from unusual. In fact, that is the way your Ed's Flight Performance and Guidance Analysis Group at Astronautics stays in business. However, digital simulations have been discussed rather infrequently at Simulation Council meetings. We are glad to see the exceptions—we always suspected those things were good for something!

way that even if all the parts were all the way to the limits of their tolerances, the assembly would still work. For years this has been an acceptable method of operation. It is often called the 'worst case' method of calculating tolerances.

"As the science of Quality Control came into being and people began to realize the statistical nature of these manufacturing variables, this method of tolerancing become intolerable!* Several methods have been formulated to interpret the idea of statistical distributions into the process of assigning tolerances, none however as general as the method of simulating the assembly by means of a digital computer. The technique discussed here was worked out on the IBM 650. Later I discovered that a similar technique is employed in the design of circuits at our Poughkeepsie plant using the IBM 704.

"Each part of an assembly will have one or more dimensions. These component dimensions take on specific values according to statistical distributions resulting from the manufacturing process. The relationship of these distributions to the tolerances on the engineering drawing and the given dimensions is frequently coincidental(!) These component dimensions are combined in some way in the assembly, and the resultant values of these critical dimensions determine whether the assembly is acceptable or not.

"There are three important points:

1. The distribution of the values of the component dimensions.

2. The relationship between the component and the critical dimensions. This is a mathematical formula for each critical dimension.

3. The limits for the critical dimensions. Beyond these points the assembly is no longer considered 'good'. Some time the distributions of these critical dimensions may be the interesting thing."

In our copy of the paper, which we are sorry to see is typed rather than produced from a master, the author describes and illustrates (with Kodacolor prints, apparently of slide projections) the computer program, first in general "to get some perspective," then in some detail.

Certainly such important work will be published in toto somewhere. And even though we can't fit all the details into the *Newsletter*, perhaps a note to the author will get you the complete word.

---

*When *is* tolerance intolerable? Sounds like the segregation issue in you-know-where!

Information (Without Theory)

A letter from our long-time acquaintance *John Lowe* informs us that the rather extensive REAC-400 installation at Douglas-Santa Monica is available on a rental basis.

* * *

DeHaas Company has announced that *Carlton Peterson* has joined the company as a sales engineer. Mr. Peterson was president of his own company, Steven-Douglas of Santa Monica, which engaged in research and development contracts in the electro-mechanical and electronics areas for seven years, but he might better be remembered for his 120' yacht and some of the parties thereon.

* * *

We have a three-language invitation to AICA—the Third International Conference on Analog Computation in Belgrade, September 4-9, 1961, but are afraid we can't make it. Perhaps the fourth one?

* * *

A 26-page report available from Computer Systems, Inc. (Culver Road, Monmouth Junction, New Jersey) describes a new and rapid procedure for the "Correlation and Optimization of Chemical Kinetics Models" with the new DYSTAC analog computer.

From this same publishing house we have an announcement that a new 16-page technical report, "Mathematical Applications of the Dynamic Storage Analog Computer" is available.

* * *

We have a letter from *Dick Bohl* (Rocketdyne, Canoga Park, Calif.) in which he says, "I would appreciate it very much if you could stimulate interest in the $\sqrt{S}$ Simulator among analog computer manufacturers." We admit we are confused (some people are very easily confused), but we believe he is referring to the section of his paper (described under Pieces) on iron-core coil response.

Letters

"Dear John:

"I am back from a short vacation which I spent mostly washing the multitude of windows in our cottage and thinking about a new graduate course which I will be starting in September: Information and Control (Cybernetics).

"Our Hall Effect effort has produced, on the practical side, a transistorized analog multiplier with attractive characteristics and considerable simplicity. My 'publication schedule' is completely messed. I have not yet finalized even last year's report on the Hall Multiplier project. So it will take probably another year before the next (and more interesting) report will be ready. . . . . .

"It just occurred to me that you may not be aware of one 'Control' development in Canada. Our National Research Council has established an 'Associate Committee on Feedback Control'; I am one of its members. All other famous names are also there (Arthur Porter, Jim Ham, d'Ombrain, etc.). We have already had two lengthy meetings and plenty of verbal output. The purpose of the Committee is to coordinate control activities in Canada and on the international level. If anything useful should develop I will let you know.

G. S. Glinski, Chairman
Electrical Engineering Department
University of Ottawa
Ottawa 2, Canada"

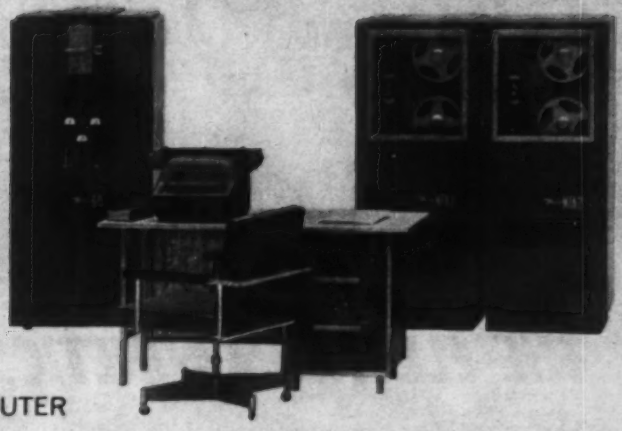
"Dear Mr. McLeod:

"I am sending you a summary of the Seminar on Analogue Methods in Nuclear Energy Problems. This will appear in Vol. 2, 3 of the Proc. of the International Association for Analog Computation. This may be of sufficient interest to you to mention this in your Newsletter.

Yours sincerely,
For Electronic Associates Inc.
R. Gomperts,
Manager Special Projects
European Division"

As members of the IAAC we receive their publications and find their international point of view very interesting. Those interested may join by sending a check for 250 Belgian francs to Association Internationale pour le Calcul Analogique, 50, Avenue Franklin Roosevelt, Bruxelles 5, Belgium. Ed.

CIRCLE 89 ON READER-SERVICE CARD ——→



ALGO*

FOR THE BENDIX G-15 COMPUTER

Speeds and Simplifies Problem Solving

ALGO extends the problem-solving horizon of every engineer, focusing the speed and precision of the Bendix G-15 computer on any algebraically stated problem. ● A true mathematical equation solver, ALGO permits any engineer or scientist to program the computer in universal mathematical language. No previous knowledge of computers or programming is needed. Input/output, computation and data handling are all automatically controlled by the G-15 computer. ● Compare the number of steps in the ALGO program illustrated below with the number required to solve the same problem on a slide rule, desk calculator or any other computing system. You will see the time and cost-saving significance of this new Bendix G-15 automatic programming aid. ● Specifically designed to take advantage of the computing power and flexibility of the proven G-15, ALGO is the newest addition to an extensive library of Bendix automatic programming systems. See how the low-cost Bendix G-15 and ALGO combine to broaden application boundaries. Learn how this powerful team can save you valuable time . . . and greatly simplify problem solving.

* AN ALGEBRAIC COMPILER BASED ON INTERNATIONAL ALGOL.

PROBLEM: $$I = \frac{E}{\sqrt{R^2 + (6.2832\,FL - 1/6.2832\,FC)^2}}$$

(For values of R F & L as specified. For values of E ranging from 100 to 300 in increments of 50. For values of C ranging from .00002 to .000021 in increments of .0000001)

COMPLETE ALGO PROGRAM:

```
BEGIN ⑤
R = 10 ⑤
F = 60 ⑤
L = ₀2 ⑤
FOR E = 100(50)300 BEGIN ⑤
FOR C = ₀00002(₀0000001)₀000021 BEGIN ⑤
I = E/SQRT(R ↑ 2 + (6₀2832 * F * L — (1/(6₀2832 * F * C))) ↑ 2) ⑤
PRINT (FL) = E ⑤
PRINT (FL) = C ⑤
PRINT (FL) = I ⑤
```

Write on your letterhead for the self-teaching ALGO manual.

Bendix Computer Division
DEPT. J-23 LOS ANGELES 45, CALIF.

THE Bendix CORPORATION

FLOW INSTRUMENTATION

JOURNAL OF THE SOUTHERN CALIFORNIA METER ASSOCIATION

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THE ELECTROMAGNETIC FLOWMETER

Most liquids (except hydrocarbons) have sufficient conductivity for flow measurement by magnetic flowmeters. Meter detects average flow velocity without introducing any obstruction in the stream.

EDWARD D. WOODRING
Fischer & Porter Company

MAGNETIC FLOWMETERS can provide an answer to those "tough" fluid flowmetering applications. Also the magnetic flowmeter has advantages for universal flow measurement.

Table 1 presents characteristics of the many types of flowmeters. Note that all of the flowmeters listed, except the magnetic flowmeter, have the following in common:

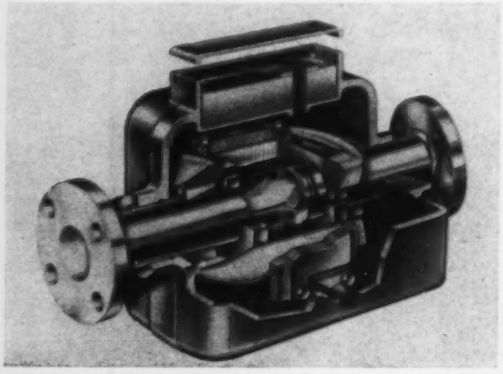
1. They are either not suitable for slurry service, or require special accessories for those applications.
2. They are or can be affected by variations in density or viscosity.
3. They are limited to certain size categories.
4. They obstruct the fluid flow and consequently develop a pressure loss.
5. They have limited rangeability (compared to the magnetic flowmeter).

These five limitations preclude the use of conventional flowmeter types on applications such as:

1. Low-head gravity flows, such as are encountered in some large-volume conduits associated with utility water-distributing systems where pressure loss cannot be tolerated.
2. The processing of food products, including beer, where the pockets, dams, crevices and corners of the wetted parts of obstructing-type flowmeters permit organic materials to be retained, which can decompose and infect the process. When obstructing types are used in these applications, they must be removed periodically, disassembled and cleaned.

Where the flow lines must be steam cleaned periodically, the magnetic flowmeter can be left in the process and cleaned as though it were another pipe section. In those processes where a ball brush is forced through the line, the magnetic meter offers no obstruction. Also obstructing-type meters cause a permanent pressure loss and pumps must be sized to handle the drop.

Other applications well-suited to the magnetic meters include sewage, oil-well drilling muds, mine and milling slurries, corrosive chemicals, some liquid plastics and blood. It is equally able to measure any of these flows in either direction.



Principle of Operation

The magnetic flowmeter operates as a simple a-c generator in which the flowing fluid is the armature and the electrodes act as brushes. Faraday's Law of electromagnetic induction states that movement of a conductor at right angles through a magnetic field produces a voltage across a direction that is mutually perpendicular to the field

TABLE 1—COMPARISON OF FLOWMETERS

Meter Type	Measures	Fluid Conditions	Scales	Sizes Lower	Sizes Upper	Pressure Loss	Rangeability (Single element)	Installation	Cost*
Magnetic Flowmeter	All liquids and slurries having sufficient conductivity. Not applicable for hydrocarbons or gases.	Unaffected by changes in density, viscosity or consistency.	Linear, Signal = f (V)	1/10"	Any	Equal to equivalent length of straight pipe.	3000:1	Any attitude. No piping limitations. Primary may be 2000' from secondary.	$900.00
Variable-Area Flowmeter	Liquids and gases. Requires purges for certain fluids and slurries.	Affected by changes in density. Under certain conditions, affected by changes in viscosity.	Linear	1"	12"	Low constant pressure drop across the meter (Approx. 2 psi for all flow rates).	12:1	Must be vertical. No piping requirements. No external lead lines required.	500.00
Orifice Plate	do*	do	Square Root. Signal = f(pV²)	1"	12"	Varies as square of flow rate. Nominal differential 1-10 psi. High permanent loss.	3 or 4:1 using square-root scale. 10:1 possible with linearizing equipment.	Straight pipe run required for approximately 10 diameters upstream and 3 downstream. Lead lines require proper arrangement. Purging or seals required for corrosive fluids or slurries.	500.00
Venturi, Flowtube, or Nozzle	do	do	do	2"	Any	Varies as square of flow rate. Nominal differential ½-4 psi. Low permanent loss.	do	do	850.00
Turbine Type	Liquids and gases. Not recommended for slurries.	Unaffected by changes in density. Under certain conditions can be affected by changes in viscosity.	Linear Signal = f(V)	<1"	12"	Pressure drop varies as square of flow rate. Approx. 7 psi at max. flow.	20:1	Any attitude. Built-in straightening vanes eliminate need for straight piping runs.	600.00
Positive Displacement	do	do	Linear Signal = f(Q)	1"	12"	Pressure drop varies as square of flow rate. Approx. 6 psi at max. flow.	20:1	Any attitude. No piping limitations.	550.00

*do = ditto, or same as above.

**Approximate cost of transmitting flowmeter to handle 100 gpm. Does not include special piping.

and to the direction of movement (Fig. 1). The voltage produced is linear and proportional to the velocity of the conductor.

Using a pipe section to support and guide the liquid flow through a magnetic field gives us a liquid conductor. Inserting electrodes through the pipe section so the ends of the electrodes are flush with the inside of the pipe provides us a means of "picking off" the voltage induced in the liquid by its movement.

As the voltage is directly proportional to the velocity of the fluid flow, with a given pipe size the flow volume will depend on velocity. Hence the induced voltage becomes a measure of the volumetric flow rate. Only the area and velocity determine the rate of flow; density or viscosity variations have no effect on the measurement.

Neither viscosity nor consistency (referring respectively to Newtonian and non-Newtonian fluids) has any effect on accuracy. The total voltage developed at the electrodes is a summation of each increment of voltage in the entire area between the electrodes. Thus, in a typical low-viscosity flow situation, as depicted in the turbulent flow profile in Fig. 1, the total voltage induced will be representative of the actual average fluid velocity as determined by the effect of each profile line.

When the viscosity increases so that the flow profile is similar to the velocity profile for laminar flow, the flow still will be determined by the summation of the voltages produced by each profile line. Therefore, the voltage received at the electrodes will be a measure of the actual average fluid velocity. Piping configurations affect the flow profile in a manner similar to changes in viscosity; measurement still shows actual average flow.

The pipe section of a magnetic flowmeter must have the following qualifications:

1. Non-corrosive or erosive to the flowing fluid.
2. Non-magnetic, so as not to affect the uniformity of the magnetic field.
3. An electric insulator, to prevent grounding of

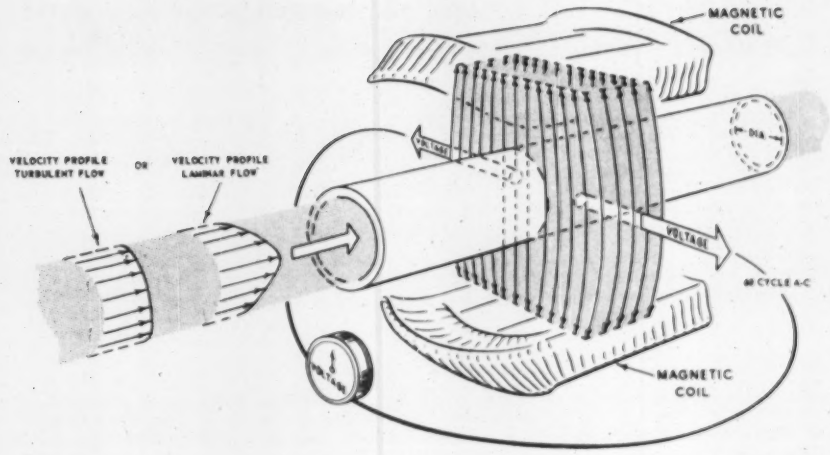


FIG. 2. PRINCIPLE of the electromagnetic flowmeter.

the induced voltage. Fiberglass satisfies these conditions and is recommended where the application permits. For other applications, a non-magnetic stainless-steel tube, lined with insulating materials such as Neoprene or vitreous enamel is used.

The electrodes must be non-corrosive and good conductors. They are mounted mutually perpendicular to the axis of the pipe and to the plane of the field. Stainless steel and Hastelloy are the most common materials used—others are platinum, Monel and tantalum.

The coils are copper wire formed into two saddle-shaped sections. The recommended insulation is a silicone-coated glass fiber in order to withstand temperature effects.

Fluid Characteristics

The fluid's qualifications are important. As the fluid must be a conductor, its electrical resistance (or, more conveniently, its conductivity) becomes an important consideration. We must be able to induce a sufficient amount of current into the fluid that can be utilized by the voltmeter or potentiometer to effect the measurement. There is a threshold conductivity below which the liquid will not give a flow reading.

When magnetic flowmeters first became commercially available about 5 years ago, the conductivity threshold below which they would not operate was about 50 micromhos per centimeter. Ordinary tap water (at Fullerton, California) has a conductivity of about 350 micromhos per centimeter. Distilled water has a conductivity of about 2 micromhos per centimeter. Hydrocarbons such as fuels and lubricating oils have conductivities less than 1/1,000,000 of a micromho per centimeter. There are certain acids whose conductivity is thousands of micromhos per centimeter, depending on their type and concentration.

The 50-micromho-per-centimeter threshold was reduced three years ago to 20 micromhos per centimeter; in 1959 the threshold went down to 10 micromhos per centimeter. In late 1959 it was again reduced to 0.1 micromho per centimeter. Technological research has dramatically lowered the threshold in less than 5 years, down to the point where most liquids now can be measured successfully.

A different approach involves introducing minute amounts of conductivity-increasing additives to the fluid stream. At this writing nothing practical has come of this idea, but it may have some applications. Also, it has been discovered that there are certain materials which by themselves have low conductivities, but when blended to certain prescribed proportions become many hundredfold more conductive that the sum of their individual conductivities.

Limitations and Precautions

Certain fluids, particularly sewage and other waste products, contain suspended low-conductivity slimes and oils that can present some difficulty. The low-conductivity material can deposit on the electrodes and effectively insulate them from the fluid voltage. Special electrodes have been furnished with brush cleaners which are operated periodically by a timer to wipe the electrodes clean. Heating units built into the electrodes also have proved to be successful in melting off an accumulation of grease. Electrodes of special shape and materials have been used successfully in specific applications.

Entrained air can affect accuracy. The indicated flow rate will be higher than the actual liquid flow rate by the amount of entrained air.

The flowmeter must always be filled with fluid. If an air pocket exists above the upper half of the pipe section, the flowmeter will indicate as though the pipe were full. If the air pocket extends below the electrodes, the meter will be open circuited and will indicate no flow.

October Meeting: Thursday, the 20th, Rio Hondo Country Club, Downey, Calif.
Feature: "The Orifice Flow Section as a Precision Instrument for the Metering of Low Flow Rates," by Thomas J. Filban, Daniel Orifice Fitting Co., Houston, Texas.

HOKE **Flow Sheet** 3

HOKE REPORTS ON FLUID CONTROL

WE'VE TOSSED A NEW BALL INTO AN OLD GAME

Do You Have A Bomb In Your Lab?

In the process industry, sampling cylinders are occasionally referred to as bombs. In recent months, this misnomer has been, unhappily, pretty close to the truth. Some military surplus, low carbon steel, two-piece cylinders have found their way into industry and have been used beyond their rather limited capabilities. Unfortunately, several serious accidents have spotlighted this use as a very real safety problem.

Since sampling is such a serious business, we have perfected, for maximum safety, a seamless, one-piece cylinder. This unabashed declaration of excellence has sound

basis in fact – the entire cylinder is formed from a single piece of seamless type 304 stainless steel tube. To quell the qualms of process men, sample contamination is practically nonexistent, and the cylinder resists destruction from most corrosives.

As a further safety guarantee, all standard sampling cylinders are fabricated to meet ICC and other safety regulations. Standard cylinders are available at pressures to 1800 psi (10 ml. to 1 gallon), but higher pressure cylinders can be had on special order.

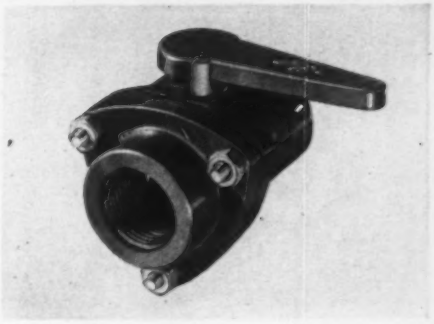
If you'd like additional information on Hoke cylinders, plus a detailed paper on the various methods of collecting samples from process lines, drop us a line. We'll also include details on special cylinder valves, outage tubes and other cylinder accessories.

The technique of molding polyvinyl chloride into ball valve parts is old hat. Even the unplasticized compounds of type I PVC have been kicked around for a while (with minor successes). But until now, no one has booted the ball for a goal.

Perseverance, determination, and the pursuit of economic reward have prompted us to offer a line of ball valves molded of the toughest grade of type I, unplasticized PVC. There are no foreign agents to contribute to a corrosive demise, even in most caustic services. It even meets the proposed new ASTM specification and has a tensile strength of 8500 psi. Those who have had PVC piping problems will profit from the new molding process that gives these Hokes dimensional stability and very high impact strength. Sensitive systems, human and otherwise, are safe from contamination – they're absolutely non-toxic. We've set 140°F. as the operating temperature limit, but occasional excursions to 160°F. won't do any harm.

All standard models are supplied with a concentric hole drilled thru the ball. They can be heat welded, or solvent bonded right in the line. Piping hook-up is even simplified by their coupling-like assembly. Your assistant can fit each half of the valve to a pipe end, then reassemble the valve without having to turn the pipe. Pressures to 125 psi are duck soup for these valves.

A maintenance man's delight, they can be cleaned and have their seats changed without leaving the pipe. Their light weight makes them ideal for use on long, unsupported spans of pipe.



Size-wise, we're offering them in ½, ¾, 1, 1½, 2, and 3 inch sizes, all NPT female connections.

You will command the eternal admiration of your colleagues when you install these valves. Be the first to show your rightful status by ordering a shiny new Hoke polyvinyl chloride ball valve. If pride of ownership hasn't motivated you at this point, the mere fact that you are behind the scientific times should move you to find out more.

It isn't necessary to tell us why you want the additional information. Just check the coupon below. We'll forward the facts in a plain, brown envelope.

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Further flow features, and interesting technical topics are carefully covered in Hoke's technical publication, the FLOW SHEET. It's free, but worth millions! To get the full benefit of our engineering and editorial efforts six times a year, mark your "X" in the proper box.

Hoke's Performance Guarantee — *Every Valve Leak-Tested!*

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31 Piermont Road, Cresskill, N. J.

Send me complete information on the Hoke products checked below:

- ☐ PVC Ball Valves
- ☐ Sampling Cylinders
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- ☐ FREE Corrosion Slide Rule
- ☐ Complete Catalog GC959

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CIRCLE 175 ON READER-SERVICE CARD

DAWN OF A NEW ERA IN INDUSTRIAL PROCESS CONTROL

introducing the first
computer system fully mated
to industrial process control....THE LIBRATROL 1000

Now for the first time your process control system can benefit from a transistorized digital computer totally designed for the modern industrial processing plant... the new, solid-state LIBRATROL*-1000. A distinguished new product of Librascope, manufacturer of the most varied line of computers in use today. Dozens of features make this the computer most likely to accelerate the current revolution in process control. **WHY THE LIBRATROL-1000 EXCELS AT INDUSTRIAL PROCESS CONTROL:** PACKAGING FEATURES...Sealed and refrigerated for long service life and reliability. Engineered for vibration resistance and ease of maintenance. INPUT-OUTPUT FEATURES...Quick-access loop speeds input of transducer data and output of commands to actuators. Numbers of transducers and actuators that can be accommodated are unlimited by hardware. OTHER IMPORTANT FEATURES...Sequencing is changeable by program. Complete random sequence, fixed sequence, or single channel. 8000-word memory. **ONLY LIBRASCOPE OFFERS CHOICE OF TWO COMPUTER SYSTEMS**...The LIBRATROL*-500 is a versatile but less expensive system...ideal for helping you develop a program of long-range conversion to automatic control...or for fully handling on-line situations not requiring all features of the LIBRATROL-1000. Either is available on a variety of purchase or lease arrangements. **CAN THE NEW ERA IN AUTOMATIC PROCESS CONTROL MEAN SIGNIFICANT IMPROVEMENTS IN YOUR COMPANY'S OPERATION?** *Find out. Write for the new Libratrol brochure with specifications and operating information. Or better still, request consultation now with a Librascope Systems Engineer versed in the control requirements of your industry.*

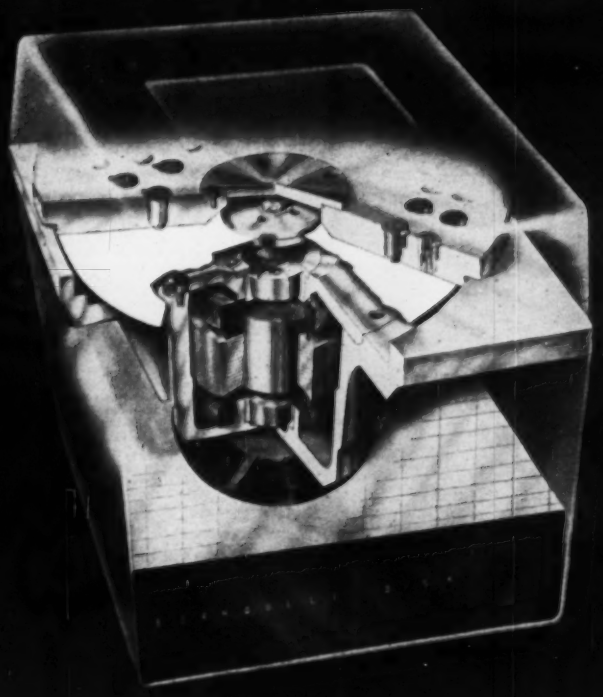
*TRADEMARK, GENERAL PRECISION, INC.

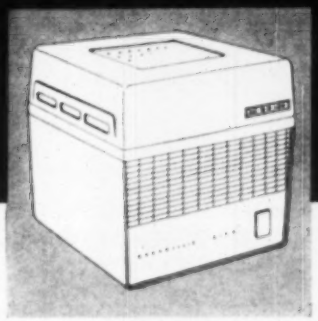
LIBRASCOPE DIVISION **GENERAL PRECISION,** INC.
Glendale 1, California

Computers that pace man's expanding mind

CIRCLE 90 ON READER-SERVICE CARD

simplest rotating storage device ever developed...





The Bernoulli Magnetic Disk Memory, a proprietary development of The LFE Applied Research Laboratory, is now available in prototype or production quantities.

The first models, designated as the BD-100 Series, are ideally applicable for use in general purpose EDP Systems. In addition, because of each unit's small size and weight, and ability to withstand severe environmental conditions, the BD-100 Series is also applicable to a wide variety of fixed station and mobile digital computers. For a complete description write for Technical Data Digest No. 607I.

SPECIFICATIONS BD-100 SERIES

Storage Capacity (Max) Bits	100,000
Bits Per Track (Max)	3,000
Bit Rate — kc	90-400
Track Layout As Required Typical:	
Total Tracks	40
Data Storage Tracks	32
Spare Tracks	3
Clock and Timing Tracks	3
Register Tracks	2
Number of Registers	4
Register Length — Bits	32
Register Adjustment — Bits	±3
Disk Speed — RPM Induction or Synchronous Motors Available	1800-8000
Power Source — cps	60-400
Magnetic Heads (Compatible with solid state circuits) Typical: (For 200 kc Operation)	
Inductance (Per Leg. — C.T. Coil) — uh	55
Write Current (P/P Manchester) — ma	250
Read Out (Min. P/P Full Coil) — mv	20
Size — Inches (Less Electronics)	9 x 9 x 5
Wide variations from typical specifications can be made to meet customer's requirements.	

LFE
Data Storage Operations
COMPUTER PRODUCTS

A DIVISION OF
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1079 COMMONWEALTH AVE. • BOSTON 15, MASSACHUSETTS

CIRCLE 84 ON READER-SERVICE CARD

DESIGNED FOR RELIABILITY THROUGH
WESTON "UNITIZED" CONSTRUCTION

COMPACT WESTON RECORDER CONTROLS TEMPERATURE OR PRESSURE ...PRECISELY...AUTOMATICALLY

The Weston Elapsed Time Controller is especially designed for batch type operations where precise timing is an important process factor. It provides interchangeability of temperature and pressure systems, and covers the complete range of Bourdon tube type instruments. All classes of thermal systems are available to suit the individual applications.
Model 7003 is activated by an external button, stops after preset interval, and automatically resets for the repeat cycle.
A large-capacity pen operates with a minimum of pressure, assuring clear, sharp records on a 12" chart.
The unit is housed in a dust and moisture-proof case which is conveniently designed for panel or wall mounting.
All internal components are mounted on the baseplate, and are integrated in a simple design for maximum efficiency and sustained accuracy.
Ask your local Weston representative for complete information on this and other Weston instruments for industry, or write for Catalog 08-705, Weston Instruments Division, Daystrom, Incorporated, Newark 12, N. J.
International Sales Division, 100 Empire St., Newark 12, N. J.
In Canada: Daystrom Ltd., 840 Caledonia Rd., Toronto 19, Ont.

Operation: 115 volts, 60 cycles. Time ranges: 1, 5, 12 or 24 hours. Minimum timer setting 4% of timer range. Pneumatic Control – 2-50% proportional band. SAMA standard electric chart drive. Rugged bridge-type pen arm suspension. 4.75" pen travel.

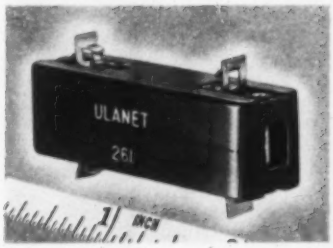
DAYSTROM, INCORPORATED
WESTON INSTRUMENTS DIVISION

CIRCLE 91 ON READER-SERVICE CARD

NEW INSTRUMENTS

THERMAL TIMER

New low-cost, completely-housed Thermal Timer, Model 261, has two terminals for the contact circuit and two terminals for the heater circuit. Available with N-O contacts which close after energizing, or N-C contacts which open after energizing the heater. Timer settings are available up to 2 min.—*George Ulanet Co., 413 Market St., Newark 5, N. J.*



CIRCLE 212 ON READER-SERVICE CARD

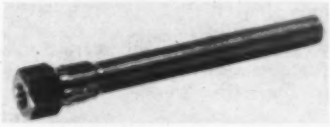
HIVAC PUMPING STATION

New 4" High-vacuum Pumping Station, VS-401, that is fully automatic achieves pump-down to $5x10^{-6}$ mm Hg in less than 35 sec, blanked port, and ultimate pressures of less than $5x10^{-7}$ mm Hg. A start button initiates the roughing cycle. Upon reaching the predetermined pressure setting, a Type TC controller automatically switches the valves from roughing to high vacuum position. After completing a process, the second, or stop button, is pressed to vent the system automatically in preparation for the next cycle.—*Veeco Vacuum Corp., Terminal Dr., Plainview, N. Y.*

CIRCLE 213 ON READER-SERVICE CARD

LOW-COST THERMOWELLS

New Econo-Wells line of Thermowells is designed to meet a variety of industrial requirements and is available in Types 304 or 316 stainless steel with various process connections and in the most commonly specified lengths.—*Trinity Equipment Corp., Cortland, N. Y.*



CIRCLE 214 ON READER-SERVICE CARD

PRESS/TEMP RECORDER

New combination electronic potentiometer Pressure and Temperature Recorder in the 8000 Series is completely self-contained and uses a constant voltage source instead of the conventional standard cell for standardization. Records one or more points of pressure and up to twenty-three points of temperature. Bulletin F-9789 describes it completely.—*Wheelco Instruments Div., Barber-Colman Co., Rockford, Ill.*

CIRCLE 215 ON READER-SERVICE CARD

FOR FURTHER INFORMATION USE CARD ON PAGE 1637

Remove all traces of OIL from compressed air lines . . .
NEW WILKERSON "WHIRLFLO"
For air lines ¼" to 5" P.T. with or without pipe flanges.

Exclusive features of NEW Wilkerson "WHIRLFLO" FILTER
★ Metal bowl or transparent bowl.
★ "Micro-Pruf" cartridge completely removes oil and particles as small as 3 microns—lasts 4 times longer.
★ 200% greater CFM capacity. Maximum pressure 250 PSI with metal bowl.

Put the "WHIRLFLO'S" double-barreled action to work for you.

1. Centrifugal force from special baffle vane sends contaminants to walls of cylinder AWAY from cartridge, from where they drain into sump.
2. Then separated air flows through "Micro-Pruf" cartridge. This 2-stage action cleans better and adds months of life to cartridge.

SAVE on maintenance and operation.
1. The cartridge lasts 4 times longer than others.
2. Cartridge is easily replaced by removing one nut while unit remains on pipe line.
3. Addition of automatic petcock eliminates human failure to drain, keeping cartridge from water level.

WRITE TODAY FOR COMPLETE INFORMATION ON THE EFFICIENT, MONEY-SAVING WILKERSON "WHIRLFLO", DESIGNED FOR INSTRUMENT PROTECTION.

WILKERSON CORPORATION
Dedicated to keeping the NEW in pNEUmatics
1619 W. Girard, Englewood, Colo.

CIRCLE 92 ON READER-SERVICE CARD

Calibrate to ±0.3 C*

with L&N Precision Checking Equipment

Growing emphasis on accuracy of temperature measurements has probably focused your attention on the need for precision equipment for thermocouple calibration.

Power plants, for instance, have found that they can substantially decrease fuel costs when turbine thermocouples are checked regularly for accuracy. In brazing processes for aircraft and missiles, where a 1.0 F variation is critical, thermocouple calibration is vital to the entire operation.

In the installation shown above, individual thermocouple wires are being checked against a platinum reference standard. The equipment consists of a:

9003 Checking Furnace	$750.00
CF-19S Alloy Equalizing Block	356.00
7553 Type K-3 Potentiometer	730.00
9834 D-C Null Detector	295.00
7308 Standard Cell	36.00
7597 Battery	23.00

Prices subject to change without notice

For more information about this equipment, contact your nearby L&N office, or write Leeds & Northrup Company, 4955 Stenton Avenue, Philadelphia 44, Pa.

* *At the fixed points.*

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"Pioneers in Precision"

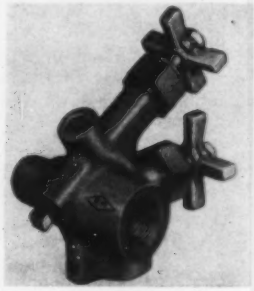
CIRCLE 93 ON READER-SERVICE CARD

AUTOMATIC TESTER

New completely-transistorized Model SCF-203 Scate (Stromberg-Carlson Automatic Test Equipment) has been engineered for wide flexibility, so that a single unit can be used to test a wide variety of equipments, with changes only in relatively simple adapters for connecting the unit to the system under test, and in the punched tape program input. Punched Mylar tape is used for programming the Scate operation, and a photoelectric reader provides checking rates up to 7,000 bits per second.—*Stromberg-Carlson, Div. of General Dynamics Corp., Rochester 3, N. Y.*

CIRCLE 216 ON READER-SERVICE CARD

DRAFT GAGE MANIFOLD

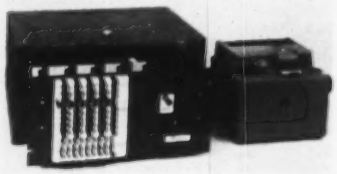


New Draft Gage Manifold Valve for pressure boiler applications makes disconnecting of lines unnecessary. The unit, singly or in multiple, is permanently connected to the compressed air supply. The gage line is shut off during blowing off of the draft line, without affecting the gage. A removable plug permits zero check, and calibration of instruments. Any number of units may be manifolded, with a separate unit for each pointer. —*Republic Mfg. Co., 15655 Brookpark Rd., 35, Ohio.*

CIRCLE 217 ON READER-SERVICE CARD

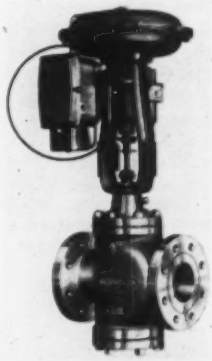
TAPE READER

New Model 200 Photoelectric Block-reading Tape Reader can read up to eighty bits simultaneously at speeds up to six blocks/sec. The solid-state, rack-mounted amplifier section has a simple plug matrix to promote line by line or block reading. Tape motion is controlled by simple photoelectric servo.—*Photocircuits Corp., 31 Sea Cliff Ave., Glen Cove, N. Y.*



CIRCLE 218 ON READER-SERVICE CARD

ELECTROPNEUMATIC POSITIONER



New Electropneumatic Positioner, Model 8010, directly compares valve stem position with controller output signal, achieving dynamic response and positioning accuracy not attainable with any transducer-plus-pneumatic-positioner combination. The E/P Positioner employs an extra large, stabilized, magnetic force motor to supply high force changes and a high-capacity air relay, for fast stroking speed. The electrical circuit is adaptable to all presently available electronic controllers.—*Mason-Neilan, Div. of Worthington Corp., 51 Nahatan St., Norwood, Mass.*

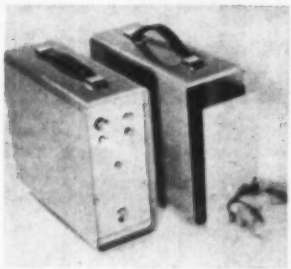
CIRCLE 219 ON READER-SERVICE CARD

VACUUM CONTROLLERS

New fully-automatic Vacuum Controllers feature continuous reading throughout the entire range and automatic reset of the control relay. Available in four ranges from 0.2μ Hg thru 200 mm Hg absolute. Control Sensitivity is within 1% of the pointer setting. Ranges are—Model VC-5: 0-100 μ Hg; Model VC-3: 0-1000 μ Hg; Model VC-4: 0-20 mm Hg; and Model VC-2: 10-200 mm Hg.—*Hastings-Raydist, Inc., Hampton, Virginia.*

CIRCLE 220 ON READER-SERVICE CARD

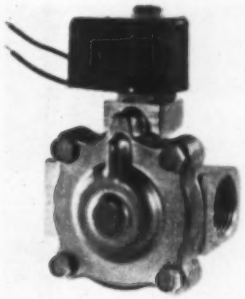
INSTRUMENT CASES



New Case for test instruments or for carrying and shipping plug-in replacement chassis permits use of snap-in terminal cards mounted in verticle planes of circuitry. All leads are brought to an easily accessible point-of-check that can be graphically identified with circuit legends.—*Alden Products Co., IC-133 N. Main St., Brockton, Mass.*

CIRCLE 221 ON READER-SERVICE CARD

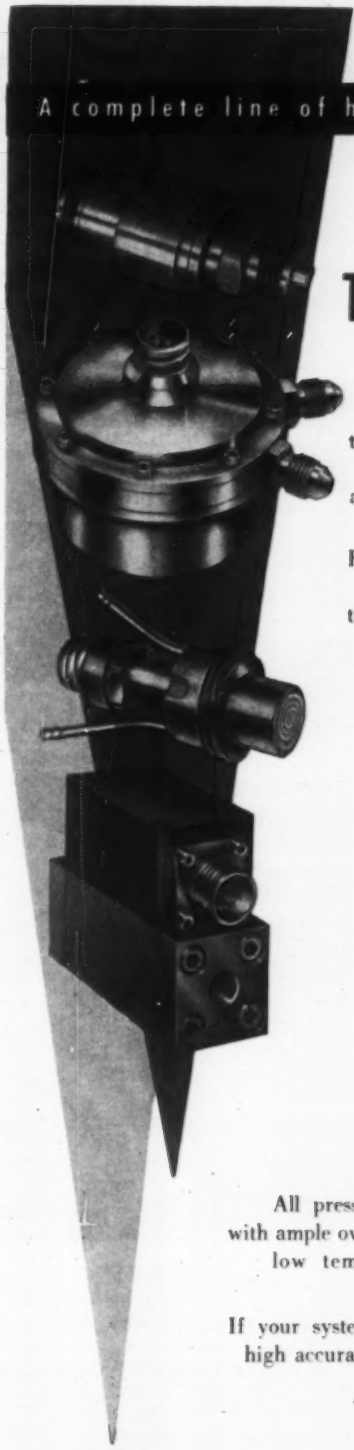
2-WAY SOLENOID VALVE



New 2-way, general-purpose Solenoid Valve, with 1" pipe connections has forged brass body and bonnet, and is available for either normally-closed or normally-open operation. Details in Form V5071.—*Automatic Switch Co., Florham Park, N. J.*

CIRCLE 222 ON READER-SERVICE CARD

A complete line of high accuracy, miniature



PRESSURE TRANSDUCERS...

to meet the in-built performance, the environmental conditions, and the reliability standards of your instrumentation system.

Here are the salient features that conclusively substantiate the performance claims of DYNISCO pressure transducers:

- **NON LINEARITY** ½ percent based on straight line through the end points
- **FULL SCALE RANGE** 0.1 psi to 30,000 psi
- **TEMPERATURE RANGE** −65 to +300° F . . . available to 500° F . . . for hot gaseous media to 6000° F
- **TEMPERATURE EFFECT** as low as 0.005 percent/FS/degF
- **HYSTERESIS** less than ¼ percent of full scale output
- **CONSTRUCTION** all welded stainless steel construction permits use in corrosive media

All pressure transducers are designed with ample overload protection, and are high and low temperature cycled to ensure stability in service.

If your system design demands reliability and high accuracy, consult our Sales Department.

Catalogs available on request.

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DYNISCO, INC.

42 CARLETON STREET, CAMBRIDGE 42, MASSACHUSETTS

Designers and Manufacturers of strain gage instrumentation

CIRCLE 94 ON READER-SERVICE CARD

IT'S WHAT'S INSIDE THAT COUNTS!

And a look inside **General Electric's potentiometric recorder** reveals how you get continuous, more reliable recordings of your process variables. Compare these important features:

1. SILICON DIODE REFERENCE VOLTAGE SOURCE

featuring plug-in design, provides continuous standardization - - - and no dry cells or standard cells are required.

2. Multi-point Selector Switch

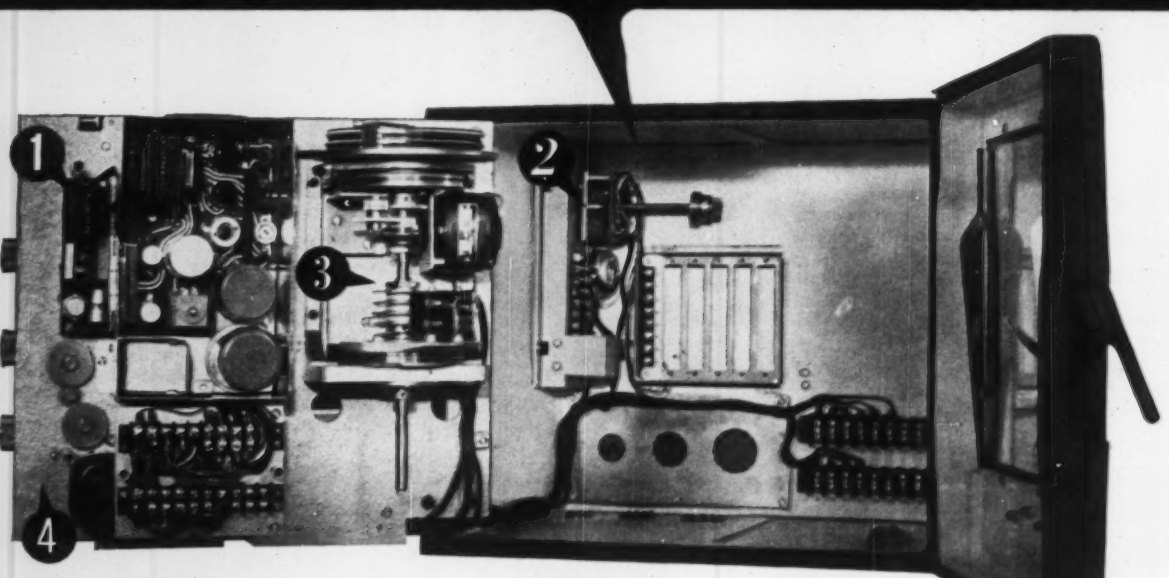
permits remote location - - eliminates long runs and multiple leads.

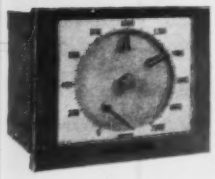
3. CONTROL SWITCHES AND SLIDEWIRES

easily accommodated - - up to 8 control or alarm switches - - up to 4 transmitting slidewires. As many as 4 switches may be adjusted by front-set index - - all switch positions independently adjustable.

4. COMPONENTS MOUNTED ON SWING-OUT PANEL

for easy accessibility include: plug-in amplifier, reference voltage unit, chart-drive motor and other measurement components.





And . . . there's a full line of General Electric recorders to choose from . . . including single-pen, two-pen and multi-point **strip-chart recorders;** plus single-pen and two-pen **round-chart recorders.**
Get the complete story on any of these recorders by contacting your nearest G-E Apparatus Sales Office today; or write for bulletins GEA-6887 and GEZ-2969, Section 599-04, General Electric Co., Schenectady 5, N. Y. In Canada, contact Canadian General Electric Co., Limited, 940 Lansdowne Avenue, Toronto 4, Ontario.

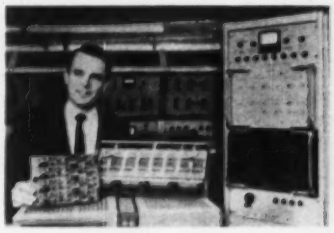
INSTRUMENT DEPARTMENT

GENERAL ELECTRIC

CIRCLE 95 ON READER-SERVICE CARD

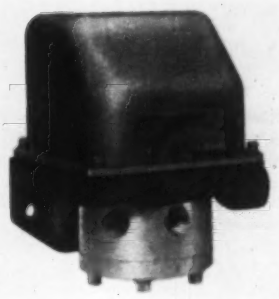
SPECTRUM EQUALIZER

New fully-automatic Spectrum Equalizer, Model AE 80/25, for random motion vibration test systems utilizes a multi-band compensation approach. The spectrum is divided into 25-cps increments. Continuous automatic equalization is achieved by using solid-state magnetostrictive filters with correct phase properties plus servo regulators on each of 80 channels in the 15 to 2000 cps spectrum.—*MB Electronics, 781 Whalley Ave., New Haven, Conn.*



CIRCLE 223 ON READER-SERVICE CARD

DIFF-PRESS TRANSMITTERS

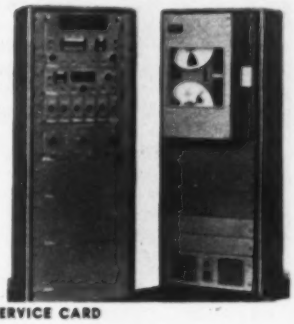


New Series BB-25 Differential Pressure Transmitters, were originally designed for detecting liquid levels in shipboard nuclear secondary plant instrumentation system. Units measure difference in pressures between two points in a fluid system and transmit the information as an electrical output which can be used directly for indication and/or control with available industrial instruments. Standard model has range from 0 to 80" WC. Units are also available to measure differentials up to 220 psi. —*Consolidated Controls Corp., Bethel, Conn.*

CIRCLE 224 ON READER-SERVICE CARD

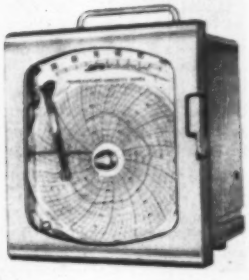
ANALOG PROGRAMMER

New Model 750 Analog Programmer is an arbitrary Function Generator wherein any single valued function (y) drawn on graph paper with conductive ink is converted to a proportional voltage as a function of time (X). Accuracy is ±0.5%; response time is less than 10 μsec. to full scale. Unit consists basically of a chart-supporting drum, a resistive roller or potentiometer, and two contact rollers.—*American Measurement & Control, Inc., 240 Calvary St., Waltham 54, Mass.*



CIRCLE 225 ON READER-SERVICE CARD

HUMIDITY AND TEMERATURE RECORDER



New Comfort Index Recorder measures temperature and humidity and records the combined measurements as the temperature-humidity index. Self-contained, and portable, it is made in two models: The Comfort Index Temperature Recorder, which indicates the Comfort Index and records both C. I. and ambient temperature; and the Comfort Index Recorder, which indicates and records the Comfort Index only. Records are on a six-inch diameter, seven-day rotation chart.—*Bristol Co., Waterbury 20, Conn.*

CIRCLE 226 ON READER-SERVICE CARD

make it a point

to visit the General Electric Instrument exhibit at the ISA show in New York, Sept. 26-30, Booth 1116-1126.

You'll see our . . .

NEW Industrial Mass Flowmeter and latest accessories for information handling in mass flow measurement.

NEW full-line null-balance Recorders for many applications, featuring latest two-pen round-chart recorder.

NEW semi-automatic leak test station for use with M-60 mass spectrometer leak detector. See our full line of halogen type leak detectors.

NEW electroluminescent 4 1/2 inch BIG LOOK panel meters and full-family panel meters.

NEW CF-8 "hook-on" watt-var recorder for utilities features quick, easy power factor determination.

NEW time meter featuring BIG LOOK appearance for matchup with G-E panel meters.

NEW low-cost AB-30 switchboard instrument featuring 1% accuracy and interchangeable scales . . . Make it a point to see how these new instruments, plus our many other quality-proved instruments, meet your applications and improve your profit picture. General Electric Instruments —the last word in measurement . . . the first in automation! 599-08

General Electric Co., Schenectady 5, New York.

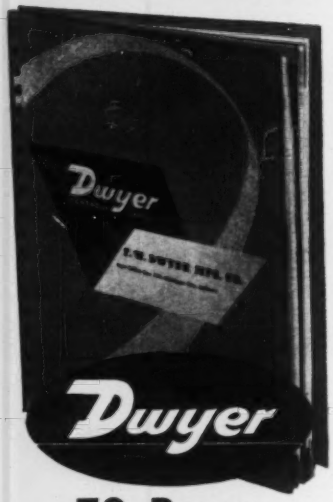
INSTRUMENT DEPARTMENT

GENERAL ELECTRIC

CIRCLE 95 ON READER-SERVICE CARD

FREE

to All Users of GAGES and CONTROLS



72-Page INSTRUMENT MANUAL

Contains:

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  - magnehelic gages
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  - air meters
  - air filter gages
  - pitot tubes
  - pressure actuated switches
  - flowmeters
  - combustion testing instruments
- Diagrams
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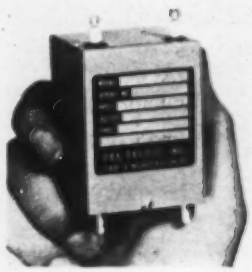
CIRCLE 96 ON READER-SERVICE CARD

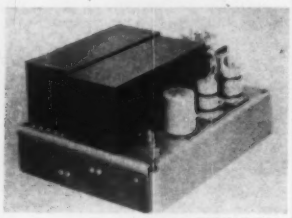
SUBMINI POWER PACKS

New Micropac-series of Subminiature solid-state high-voltage d-c Power Supplies provide regulated voltages ranging from 1000 to 5000 vdc while featuring extremely small size and light weight. Units are available for operation from a 60- or 400-cycle line, in addition to a 26-29-vdc line. Line regulation of ±0.5% is provided along with load regulation of ±0.5% for 20-100% load changes. Ripple is 1% rms. Standard voltages available are 1000, 3000, and 5000 vdc at maximum load current of 100 μamp.—*Era Pacific, Inc., 1760 Stanford St., Santa Monica, Calif.*



CIRCLE 227 ON READER-SERVICE CARD

PRECISION POWER SUPPLY

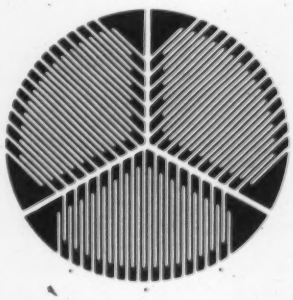


New Precision Power Supply uses advanced circuitry to achieve performance compatible with precise computation, including applications of inertial guidance integration. Outputs are ±25 v, both maintained to better than ±0.01%.—*Kearfott Div., of General Precision, Inc., 1150 McBride Ave., Little Falls, N. J.*

CIRCLE 228 ON READER-SERVICE CARD

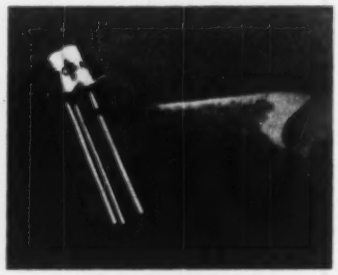
ROSETTE STRAIN GAGE

New Single-plane Rosette Strain Gage is very thin thus minimizing errors encountered in bending measurements. It has a maximum of sensing elements in a given area thus enabling measurements closer to a point than available with any other single plane rosette. Available in ½" and ¼" sizes, in 45° and 60° configurations as well as on epoxy, paper or phenolic matrices.—*Baldwin-Lima-Hamilton Corp., Electronics & Instrumentation Div., 42 Fourth Ave., Waltham 54, Mass.*



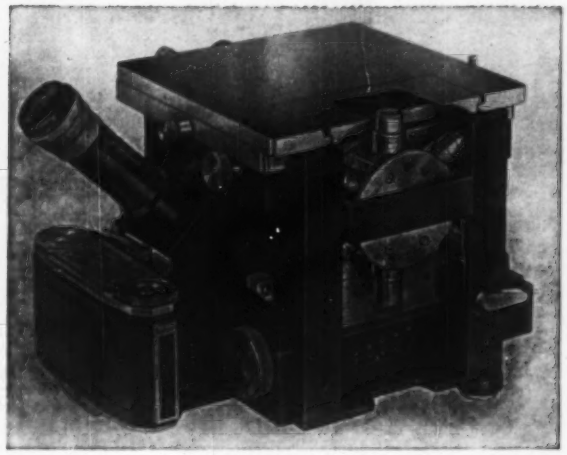
CIRCLE 229 ON READER-SERVICE CARD

SILICON MESA SWITCHER



New Model 2N706A, is called industry's fastest Guaranteed Silicon Mesa Switcher. Eight exclusive *guaranteed* features are: d-c beta ranges of 20 to 60; lower T_s (charge storage time constant) of 25 nsec max; lower output capacity from 6pf to 5 pf; turn-on time (T_{ON}) of 75 nsec max; minimum BV_{CEO} of 15 v at a sustaining current of 10 mamp; and maximum $I_{CER(RBE=100K)}$ of 10 uamp at 20 v V_{CE} (which gives a practical "switch-off" test).—*Texas Instruments Inc., Box 312, Dallas 21, Tex.*

CIRCLE 230 ON READER-SERVICE CARD



Write for detailed literature and specifications on this industrial microscope.

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For accurately measuring minute depths of roughness of super-finished surfaces, thickness of coatings, changes of surface structures due to wear, impact, stress, strain, corrosion, as well as for the studying of polished and etched metallurgical specimens.

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CERAMIC
COBALT FERRITE
COPPER
*CORNING 707
*CORNING 7052
COPROUS BROMIDE
FERRITE
FERROX
**FLUORIDE, CALCIUM
**FLUORIDE, LITHIUM
GALLIUM ANTIMONIDE
GALLIUM ARSENIDE
GARNET
GERMANIUM
GOLD
INDIUM ANTIMONITE
INDIUM PHOSPHIDE
INDOX
IRON SINGLE CRYSTAL
LITHIUM
MAGNETIC PLUMBITE
MELAMINE FIBER GLASS
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NICKEL OXIDE
PLATINUM
POTASSIUM BROMIDE
*PYREX
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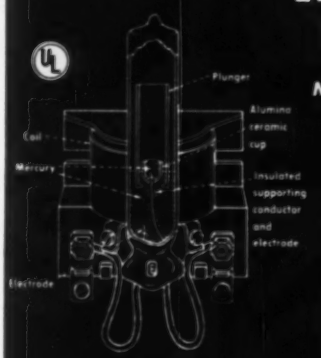

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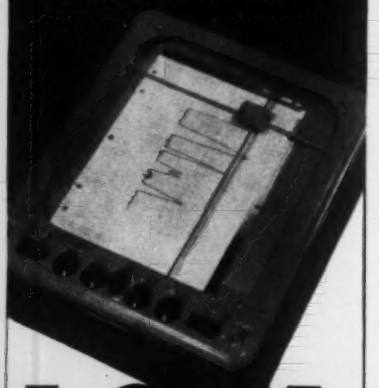
HR-92 X-Y
X-Y RECORDER
Unconditionally
Guaranteed For One Year



LOW $595.00 COST

- Flat bed — Full Chart visibility
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- Critically damped response
- Clip-on pen — Interchangeable for multicolor traces
- Standard 8½ x 11 paper

RUGGED "All Purpose" X-Y RECORDER

The HR-92 is a null-seeking servo-type plotter designed to draw curves in Cartesian coordinates on regular 8½ x 11 graph paper. Control panel has zero set and continuously-variable attenuator for each axis. Separate standby and power switches are provided. Two axes are electrically and mechanically independent.

- Amplifiers easily removed if servicing ever becomes necessary. Electrical connections all contained in two plugs for each amplifier.
- Each amplifier channel (including transformer power supply) independent of rest of system.

WRITE FOR:
New X-Y Recorder Circular #792-4 showing complete specifications and photographs.

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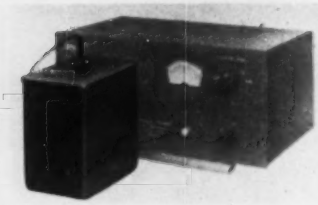
CIRCLE 100 ON READER-SERVICE CARD

CARY SHIELD ENCLOSURE



New Cary Shield Enclosure provides a fast, convenient means of shielding materials and small components when precisely monitoring their electrical characteristics with Cary Model 31 and 32 electrometers. Applications include measurements of high value resistors, charging phenomena, and electrical properties of semiconductors and insulating materials. Resistance measurement from 10^6 ohms up to 10^{15} ohms may be made at a potential of 1 v with ±1% accuracy. Capacitor insulation resistance may be measured on capacitors of 0.01 mf or smaller.—*Applied Physics Corp., 2724 South Peck Rd., Monrovia, Calif.*

CIRCLE 231 ON READER-SERVICE CARD

TOTALIZING COUNTER

New line of laboratory and industrial Counters uses cold cathode counting tubes with transistorized drive circuits. Units operate from photoheads or 5-v pulses supplied by other sensing devices. Specifications of the Model NPT Totalizing Counter include a speed of 30,000 counts/min and life of over 1,000,000,000 counts. The counter can be manually or electrically reset and can be modified to count by 2, 3, 6, or 12.—*Ardwin Microlab Inc., 21 Spencer St., Stoneham 80, Mass.*

CIRCLE 232 ON READER-SERVICE CARD

CAMERA ACCESSORIES

New Accessories for the Pathe 16-mm camera include 200-ft and 400-ft Magazines, Electric Motor, Tachometer, and many other professional items.—*Burke & James, Inc., 321 S. Wabash Ave., Chicago 4, Ill.*

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SINCE 1902 Klipfel VALVES

provide AUTOMATIC CONTROL of
TEMPERATURE • PRESSURE
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available for
STEAM • GAS • AIR • WATER
CHEMICALS
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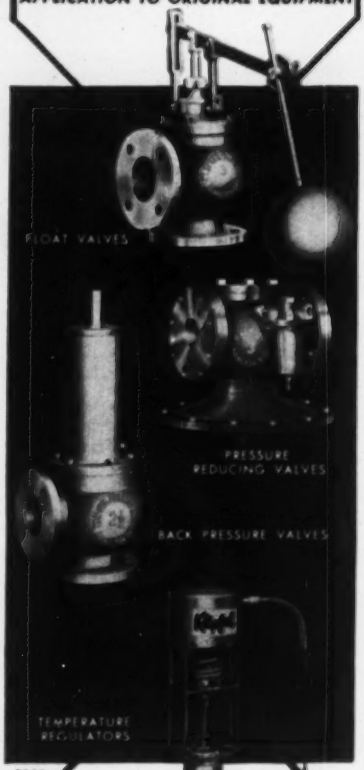
APPLICATION TO ORIGINAL EQUIPMENT



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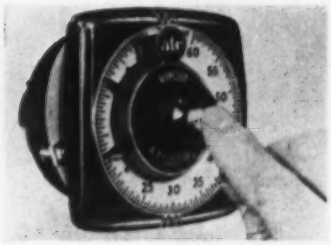
CIRCLE 101 ON READER-SERVICE CARD

PUSH-BUTTON TIMER



New Model 309 Atcotrol Push-Button Timer available for either ac or dc operation provides automatic shut-off and reset and features (1) 0.0025 repeat accuracy; (2) an exclusive metal-to-neoprene impingement clutch; (3) one SPDT snap-action load contact in series with the motor, plus option of additional SPDT snap-action independent load contact. Available in 16 standard dial ranges from 6 sec to 60 hrs.—*Automatic Timing & Controls, Inc., King of Prussia, Penna.*

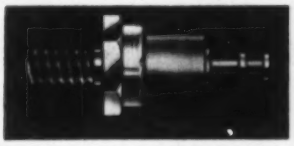
CIRCLE 234 ON READER-SERVICE CARD

DIELECTRIC STRENGTH TESTER

New D-C Hypot Jr. Dielectric Strength Testers, weighing only 20 lb and operating from 110-v a-c sources, affords d-c breakdown and leakage tests of insulation at potentials to 5000 v. Operation is virtually automatic, once set to the desired d-c output potential. Three models are offered, with output continuously variable from 0-1500, 0-2500 and 0-5000 vdc.—*Associated Research, Inc., 3777 W. Belmont Ave., Chicago 18, Ill.*

CIRCLE 235 ON READER-SERVICE CARD

TERMINALS & FEED-THROUGHS



New line of Insulated electronic hardware includes (1) Terminals set in molded phenolic, melamine, or ceramic which are silver plated with cadmium plated bases, except those on ceramic items which are gold over silver plated, and (2) Miniature Insulated Stand-offs.—*Goe Engineering Co., 219 S. Mednik Ave., Los Angeles 22, Calif.*

CIRCLE 236 ON READER-SERVICE CARD

BY DEFINITION...

A PRECISE-POWER SET is a rotary electro-mechanical system, statically regulated, which performs **one or more** of the following functions:

Isolates the DC power system from static and/or transient power line changes.

Raises the power-line frequency, reducing the cost, size, and complexity of the system power supplies.

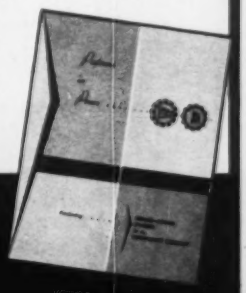
Performs the conversion to (regulated or unregulated) DC directly.
Multiple outputs are common.

BEST FOR LARGE ELECTRONIC SYSTEMS

Don't freeze your designs for large electronic power-supply systems until you have given mature consideration to the striking advantages obtained by interposing a PRECISE-POWER SET between the power line and your electronic-circuit loads.

Designers who worry about reliability, cost, size, and weight—particularly those working in the fields of computing, automation, telemetry, missile checkout and guidance, process control—will find our complete and authoritative 32-page technical bulletin S-59 of great interest.

Why pay for, make room for, **suffer** for the 25%-55% of excess power dissipation forced on regulated DC power supplies by power-line fluctuations, when a compact, maintenance-free PRECISE-POWER SET will pay for itself several times over, and virtually eliminate them?



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CIRCLE 102 ON READER-SERVICE CARD

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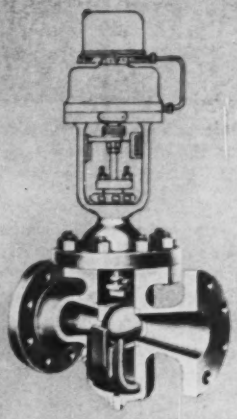
REPAIR

In the most critical applications the unique Venturi-ball design of the P-K Paul Valve has consistently surpassed conventional valves in uninterrupted hours of operation. Since the ball of the P-K Paul Valve presents an infinite number of contact surfaces to the metal seat, down time caused by erosion, abrasion and wire-drawing is reduced to an absolute minimum.



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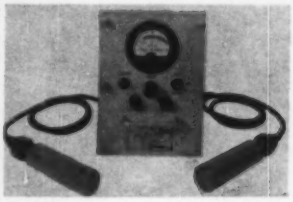
CIRCLE 103 ON READER-SERVICE CARD

CONDUCTIVITY METER

New direct-reading Conductivity Meter, Model RA-1, for demineralized water provides for measurements at two separate points with a switch on the front panel for selecting the appropriate conductivity cell. All components are in accordance with MIL specs.—*Industrial Instruments, Inc., 89 Commerce Rd., Cedar Grove, N. Y.*



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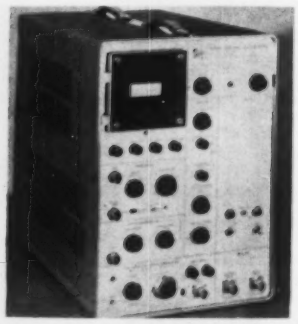
HI-SPEED OSCILLOSCOPE



New Type 519 KMC Oscilloscope is a calibrated, high-speed, laboratory instrument for wide-band phenomena. Performance features include: passband from dc to beyond 1000 Mc, risetime of 0.35 μsec, sensitivity of 10 v/cm, linear sweeps to 2 nsec/cm, and sweep delay to 35 nsec. All features (including a senitive trigger system) are fully compatible with the signal bandwidth capabilities of the instrument. Bulletin A-20005 gives details. —*Tektronix, Inc., Box 500, Beaverton, Ore.*

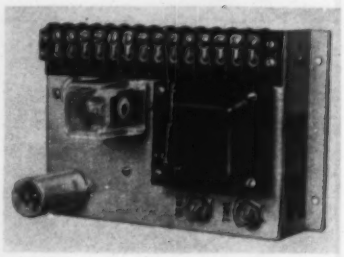
CIRCLE 238 ON READER-SERVICE CARD

PORTABLE RECORDER

New self-contained, single-channel Direct Writing Oscillograph is available in two models—Model 299 with general-purpose d-c amplification, Model 301 with an a-c carrier amplifier. Both provide readout in clear inkless traces on rectangular coordinate, 40-div. charts. Maximum sensitivity for the transistorized Model 299 is 10 mv/chart div., and frequency response is dc to 100 cps within 3 db at 10-div. peak-to-peak amplitudes. Maximum sensitivity for the Model 301 recorder is 10 μv rms/chart div. and frequency response is dc to 100 cps within 3 db at 10 div. peak-to-peak.—*Sanborn Co., Industrial Div., 175 Wyman St., Waltham 54, Mass.*

CIRCLE 239 ON READER-SERVICE CARD

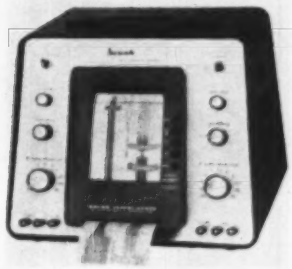
PHOTOEL SCANNER RELAY



New Type PE5 Photoelectric Scanner Relay monitors the movement of parts through handling systems. Delay can be as little as 50 msec or up to 1½ sec. Various light-source/photocell combinations permit choice of scanning distance and use of direct light or of the Farmer Proximity Sensor. The DPDT plug-in relay handles an 8-amp non-inductive load at 115 vac.—*Farmer Electric Products Co., Inc., 2300 Washington St., Newton Lower Falls, Mass.*

CIRCLE 240 ON READER-SERVICE CARD

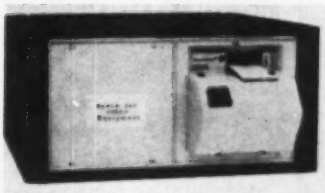
ELECTRIC WRITING FEATURE



New Mark II Model 2522 portable Electric Writing Recorder allows instant recording of two channels of analog data and two channels of coded, event- or time-data on a common time base. Four chart speeds can be selected instantly and positively from pushbutton controls on the face of the recorder panel.—*Brush Instruments, div. of Clevite Corp., 37th & Perkins, Cleveland 14, Ohio.*

CIRCLE 241 ON READER-SERVICE CARD

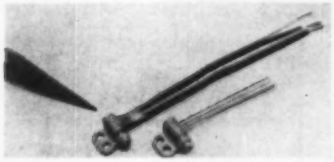
HIGH-SPEED PRINTER



New High-speed Printer is designed to record the readings of Beckman Counters, Model 1453. Readings of up to 12 digits are printed in black or red on command, thus making it possible to distinguish between two sets of data on the same tape. It may be actuated by a standard 1-2-4-8 binary code as well as the 1-2-2-4 code generated by Beckman counters.—*Beckman Instruments, Berkeley Div., 2200 Wright Ave., Richmond, Calif.*

CIRCLE 242 ON READER-SERVICE CARD

INSTRUMENT RECTIFIER



New low-priced Series 160-U Instrument Rectifiers, available either in selenium or copper oxide, feature all-metal structure, dual mounting holes, choice of wire or filiform leads, and a selection of finishes. All units are color coded. A selection of all standard and special configurations is available.—*Conant Labs., Box 3997, Bethany Station, Lincoln, Neb.*

CIRCLE 243 ON READER-SERVICE CARD

HEISE GAUGES

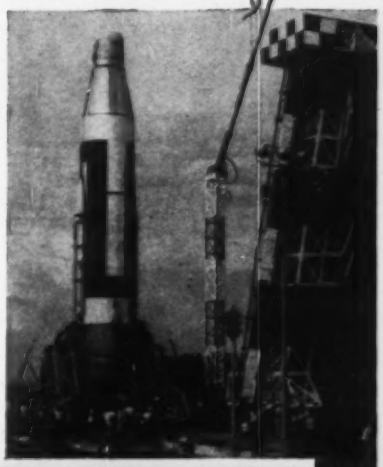
Critical Test Procedure

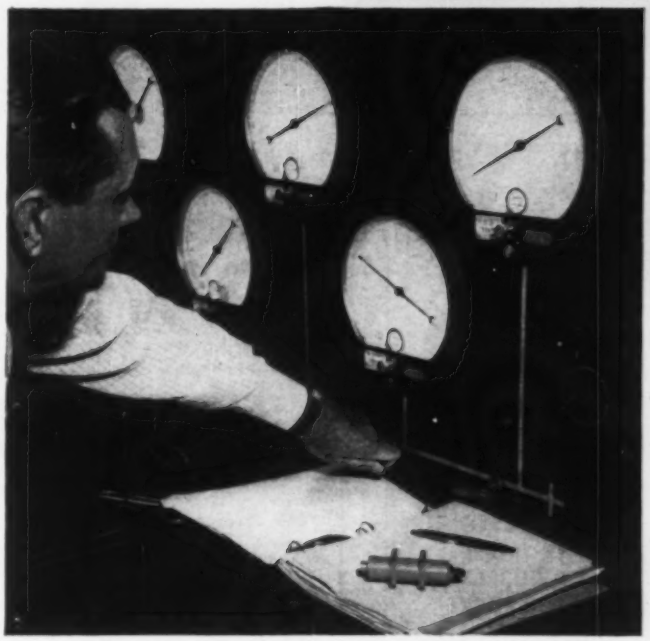
Analysis of ICBM components, such as the airborne transducer being tested here in the Standards Laboratory of Convair Astronautics, requires a superior "Test" instrument.

The Heise precision pressure gauge used for this work surpasses the highest rating for test gauges covered by the American Standards Association.

All Heise gauges are accurate to 0.1 of 1% of full scale reading.

ASA Grade AA test gauges are accurate to 0.5 of 1% of full scale reading.





The above photographs of the Atlas ICBM and the test stand featuring Heise Gauges were supplied by Convair (Astronautics) Division, General Dynamics Corporation, manufacturer of the Atlas.

The Atlas is designed to deliver a thermonuclear war head 6,325 statute miles.

PRESSURE RANGES	DIAL SIZES	PRICES	DELIVERY
15 to 100,000 P.S.I.	8½", 12", 16"	from $183.50	within 30 days

HEISE BOURDON TUBE COMPANY, INC.

BROOK ROAD, NEWTOWN, CONNECTICUT, U.S.A.

CIRCLE 104 ON READER-SERVICE CARD

New Marconi Capacity Bridge enables difficult measurements such as temperature co-efficients, circuit strays and tube interelectrode capacities to be easily made. Capacitors already wired into circuits can be checked **without removal** by the three terminal "in situ" method.

Model 1342 uses the transformer ratio arm technique which permits measurement of small capacities at the end of long screened leads to be measured without loss of accuracy.

Brief Specification

Range:	**0.002 to 1,111 μμF**
Accuracy:	**±0.2%**
Resistance range:	**1 to 1000 MΩ**
Frequency:	**1 Kc**

Decimal point inserted automatically

MARCONI INSTRUMENTS

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CIRCLE 105 ON READER-SERVICE CARD

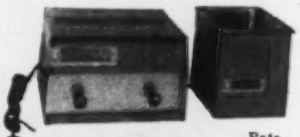
HARDNESS TESTING

SCLEROSCOPE
FOR TESTING THE HARDNESS OF METALS. PIONEER AMERICAN HARDNESS STANDARD. OVER 40,000 IN USE. (ASTM A427)

DUROMETER
FOR TESTING THE HARDNESS OF RUBBER & RUBBER-LIKE MATERIALS (ASTM D676) (ASTM D1484) (ASTM D1706)

SHORE INSTRUMENT & MFG. CO., INC.
90-35 VAN WYCK EXP.
JAMAICA 35, N. Y.

CIRCLE 106 ON READER-SERVICE CARD



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Choice of 7 beautiful decorator colors to harmonize with your office or laboratory decor: Ivory, Wheat yellow, Turquoise, Desert sand, Pale green, Soft gray and Coral pink. Please specify color when ordering.

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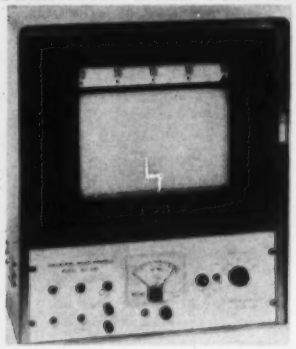
ultrasonic industries

CIRCLE 107 ON READER-SERVICE CARD

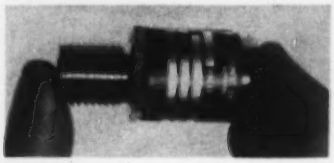
IONIZATION GAGE CONTROL



New Vacuum Ionization Gage Controller features automatic, bi-directional range selection, from 10^{-4} to 10^{-9} mm Hg, with output on a logarithmic strip-chart recorder as standard; a panel meter with adjustable limit contacts; control of accessory equipment from vacuum; and plug-in electrometer amplifier.—*F. J. Cooke, Inc., 145 Water St., So. Norwalk, Conn.*

CIRCLE 244 ON READER-SERVICE CARD

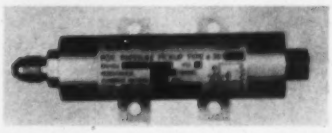
PRESSURE SWITCH



New Dual-Snap Miniature Pressure Switch, Model 608 GC, provides vibration-proof operation. Operating range is 2 to 750 psi, proof pressure is 4500 psi, temperature range −65° to 250°. Special versions are available with 10,000 psi proof pressure and a temperature range from −340° to 1000°. S-s pressure capsule handles any media compatible with Type 347. SPDT switch is UL approved, rated 5 amp 125, 250, 460 vac, and 5 amp 28 vdc.—*Custom Component Switches, Inc., 3137 Kenwood St., Burbank, Calif.*

CIRCLE 245 ON READER-SERVICE CARD

PRESSURE TRANSDUCER



New Type 4-383 Potentiometer Pressure Transducer combines high vibration resistance with superior linearity to assure precise accuracy. Maximum deviation due to the effects of linearity, hysteresis, repeatability, and friction is less than ±1%. Withstands up to 35 G's acceleration at 2000 cps.—*Consolidated Electrodynamics Corp., a subs. of Bell & Howell, 360 Sierra Madre Villa, Pasadena, Calif.*

CIRCLE 246 ON READER-SERVICE CARD

Only GREIBACH PRECISION METERS

GIVE YOU
BETTER THAN
¼% ACCURACY

...DESIGNED-IN, CONSTANT, GUARANTEED

Greibach-patented Bifilar no-friction movement and weightless light beam pointer use no pivots, no jewels, no hairsprings, no amplifiers. Greibach meters start with near-perfect accuracy. Accuracy is ***unaffected even by overloads of 100,000%*** (to 125,000,000% in some cases). Rugged, shock-proof design cradles the coil; withstands up to 500 G's. There's nothing to wear, vary or age with use, so accuracy remains high over long periods. Most meters leave our plant with measured accuracy of better than 1/10%.

OTHER EXCLUSIVE GREIBACH PRECISION METER FEATURES:

- Sensitivity to 0.2 μamp. full scale
- Resistance to 1/300th of conventional meters
- Energy drain as low as 4×10^{-10} watt
- No parallax errors from any reading angle
- Multpile Ranges—up to 23 in one meter.

The secret of Super-Precision Performance is in this cartridge, containing unique Bifilar Suspension.

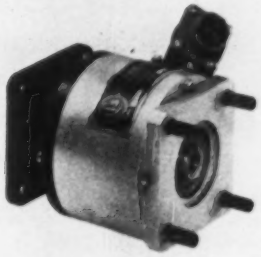
For full details on the thousands of range-combinations available, write, wire or phone today for detailed 20-page catalog.

GREIBACH INSTRUMENTS CORPORATION

331 North Ave., New Rochelle, N. Y.
Phone: NEw Rochelle 3-7900

CIRCLE 108 ON READER-SERVICE CARD

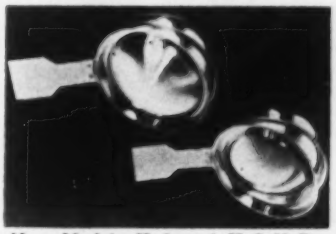
PRECISION MAGNETIC PICKUP



New high-speed Magnetic Pickup Model 2043 that permits accurate measurement of rpm, designed for sandwich mounting between a tachometer generator and an AND-20005 engine mounting pad, can deliver high-level signals to operate remote frequency counters or recording instruments located, in some installations, up to 500 ft. Standard operating frequencies are 60 to 120 pulses/rev.—*ILS Electronic Div., Meriam Instrument Co., 10920 Madison Ave., Cleveland 2, Ohio.*

CIRCLE 247 ON READER-SERVICE CARD

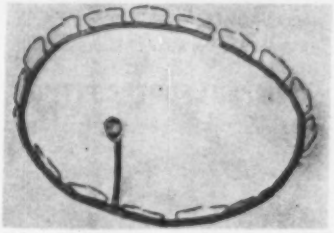
RUPTURE DISCS



New Models H-O and H-O-V Rupture discs withstand operating pressures closer to rupture pressure than has been considered acceptable for conventional prebulged rupture discs. They range in size from ⅛" through 30" and are made for pressures ranging from 5 to 50,000 psig. Assemblies are available three designs.—*Fike Metal Products Blue Springs, Mo.*

CIRCLE 248 ON READER-SERVICE CARD

HI-TEMP HARNESSES



New Harness Assemblies meet high temperature demands of modern thermocouple thermometry and are grouped into a stainless-steel covered flexible harness which makes possible several important advantages of economy and performance.—*Harco Labs., Inc., 77 Olive St., New Haven, Conn.*

CIRCLE 249 ON READER-SERVICE CARD

TEFLON* TUBING

for your

TOUGHEST PROBLEMS ON

Laboratory Constructions

Special Apparatus

Instruments

PF Teflon furnishes easy-fabrication solutions to difficult application problems because of its unique chemical, electrical and mechanical advantages. Wherever tubing has a critical job to perform in electrical, electronic, chemical, food, laboratory, mechanical and other applications, PF Instrument Tubing is the best answer because it:

1. Has an extreme service temperature range from −320° to 500°F.
2. Has excellent dielectric properties and zero moisture absorption
3. Resists almost all chemicals and solvents
4. Is easy to clean or sterilize
5. Is translucent, tough and flexible
6. Will not contaminate a stream

PF extrudes this tubing to all popular sizes from .012" to .330" I.D., thin and standard wall, in a full range of colors.

The combination of Teflon's outstanding properties and PF's outstanding engineering and manufacturing techniques can help solve your difficult application problems.

Write, wire or phone for information and advice on your specific application

PENNSYLVANIA FLUOROCARBON CO., INC.

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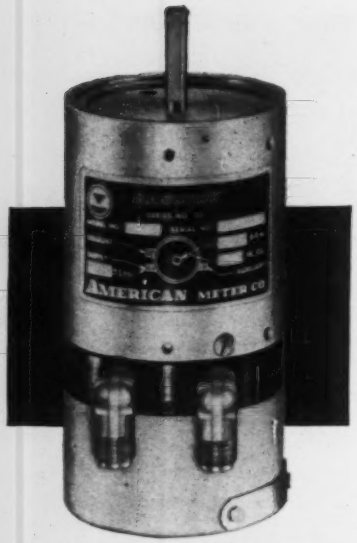
Philadelphia 4, Pa.
PHONE: EVergreen 6-0605
TWX: PH 252

*Reg. U.S. Pat. Off.

CIRCLE 109 ON READER-SERVICE CARD



AMERICAN®

GASCLOK POWER DRIVE

Completely self-contained gas or air-powered instrument driving and timing unit for long, trouble-free operation in remote locations. The GASCLOK delivers more than 20 times the torque of conventional spring-wound mechanisms. Continuous timing accuracy is unaffected by a ± 20% variation in supply pressure.

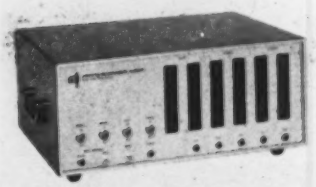
Inherently explosion proof and self-starting, the GASCLOK is ideal as original or replacement equipment for strip chart and conventional circular chart instruments. The timing mechanism is internally sealed to prevent corrosion, and all power unit parts exposed to gas are aluminum or stainless steel. Large area internal ports prevent clogging. Normal air or gas consumption 5 cfh . . . operating pressure 5 psi . . . rotation 2 rpm.

AMERICAN®
METER COMPANY
INCORPORATED (ESTABLISHED 1836)

Executive Offices: Philadelphia 16, Pa.
Sales offices in principal cities.

CIRCLE 110 ON READER-SERVICE CARD

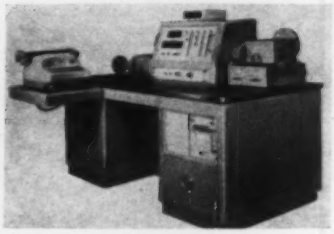
DIGITAL CLOCK



New Digital Clock, Model 224A, provides three basic clock functions: digital time display, digital time in 1-2-2-4 coded output form, and elapsed time measurement with digital time display and coded output. Real time or time measurement is displayed in hours, minutes, and seconds. The internal 1-cycle clock pulses are generated by synchronization with the 60-cycle power line (0.1% nominal accuracy) or by external sources, such as a crystal-controlled time generator.—*Computer-Measurements Co., Sylmar, Calif.*

CIRCLE 250 ON READER-SERVICE CARD

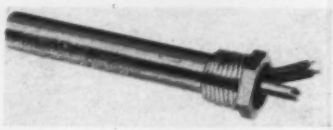
DIGITAL CONTROL SYSTEM



New completely transistorized, plug-in Automatic Digital Recording and Control System (ADRAC) is specifically designed for monitoring and controlling up to 10 analog computers of 10,000 inputs each. Without human intervention, and via punched tape, it can select a computer, place it into any one of its operating modes, set the computing elements such as potentiometers with an accuracy of ±0.01%, read back the voltage variables to check settings of computing elements, and then initiate problem solution.—*Computer Systems, Inc., Culver Rd., Monmouth Junction, N. J.*

CIRCLE 251 ON READER-SERVICE CARD

TEMPERATURE CONTROL

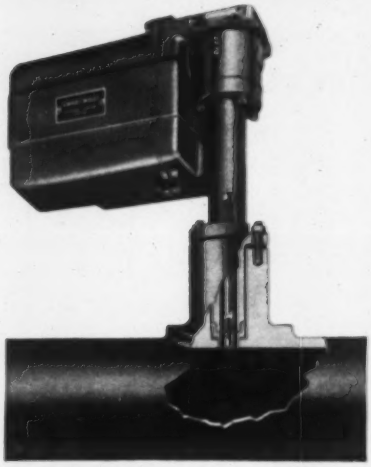


Two new low-cost adjustable Thermoswitch temperature controls are moisture resistant. Sensitivity is a fraction of a degree. Model 17100-161 has a range of 0 to 175°F; Model 17100-162 has a range of 0 to 225°F.—*Fenwal Incorporated, Pleasant St., Ashland, Mass.*

CIRCLE 252 ON READER-SERVICE CARD

Great things are happening in AutroniC® Control

TOUGH PROBLEMS ARE NO PROBLEM



FOR THIS FOOLPROOF, FOUL-PROOF PRESSURE TRANSMITTER

Here is a primary sensing element for those tough jobs you'd like to forget. Mounted right on the process pipeline or tank, the Swartwout Flush Diaphragm Pressure Transmitter will effortlessly measure pressure or liquid level of polymers, slurries, asphalts, viscous fluids, molten metals and other difficult media. No stagnant pressure lines, no steam jacketing necessary . . . the stainless steel transmitter diaphragm fits flush with the inside of the vessel.

A friction-free linkage multiplies diaphragm motion and actuates the core of a differential transformer to produce a 0-0.5V AC signal for any Swartwout AutroniC indicator, recorder or controller. Sensitivity is better than 0.005%, reproducibility 0.1%, accuracy 1.0%.

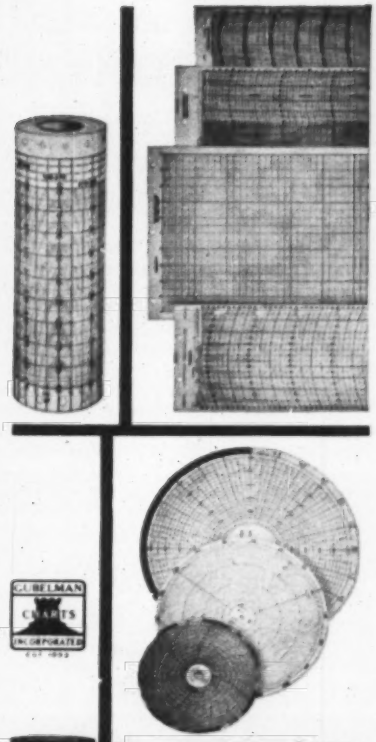
The Flush Diaphragm Pressure Transmitter is just one unit in the constantly-growing AutroniC family of electronic instrumentation . . . a family that includes all necessary components for complete electronic control of any process parameter.

For details on the Flush Diaphragm Pressure Transmitter, request Bulletins A-713 and A-718. Swartwout Division, Crane Co., Hooksett Industrial Park, Manchester, N.H.

SWARTWOUT

. . . world leader in electronic process instrumentation

CIRCLE 111 ON READER-SERVICE CARD



CHARTS

for Recording Instruments

We offer to the Instrument Maker Charts for all methods of Recording: Pen, Ball Point, Electrical, Thermal, Pressure and Metallic Stylus.

Precise quality control of materials, modern specialized equipment operated under controlled atmospheric humidity conditions by highly skilled and experienced personnel combine to produce Charts of uniformly high accuracy.

GUBELMAN
CHARTS INCORPORATED
100-6 E. KINNEY ST., NEWARK 5, N. J.

ENVIRONMENTAL CHAMBER

New Hot-Cold-Humidity Chamber using liquid CO_2 for cooling features a control system with dry bulb-net-bulb program recording controller which gives accuracy of control in both the heating and cooling cycles. The chamber drops to $-100°$ F in a few minutes. Accuracy of control is better than $\pm 1°$ F. Illustrated is a Model C8CO_2 front opening chamber. *—Development Engineering Co., Inc., 9 Cross St., Norwalk, Conn.*

CIRCLE 253 ON READER-SERVICE CARD

PERFORMED TAPE READER

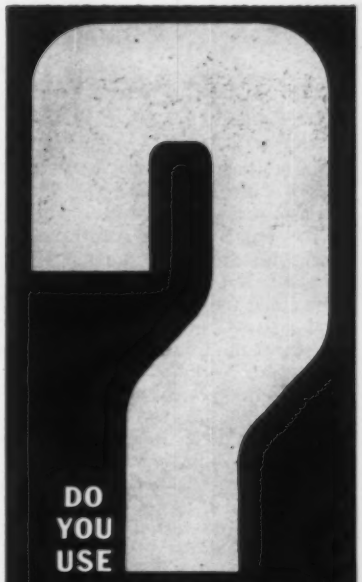
New bi-directional high-speed Perforated Tape Reader, Model B3500, operates on loops or strips of tape. Part of the completely transistorized circuits are two flip-flops which provide reliable control of the four solenoids used to control start and stop in either direction. The standard unit is complete with an 8 level plus sprocket reading head, power supply, gating and shaping circuits, and amplifiers.*—Dykor Tape Reader Div., Digitronics Corp., Albertson, L. I., N. Y.*

CIRCLE 254 ON READER-SERVICE CARD

HIGH VOLTAGE SUPPLIES

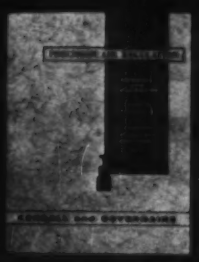
Two new models High-Voltage Supplies feature long term stability, superior transient response and very low noise. Based on the ORNL-Q-2057 design they make use of 85A2 gas reference tubes for coarse control. For fine control the Model 40-6 also uses Zener diodes. All switch positions are calibrated directly in volts. Each unit is only 3½" high and is suitable for rack mounting. Both instruments have positive and negative output voltage connectors.*—Radiation Instrument Development Lab. Inc., 61 East North Ave., Northlake, Ill.*

CIRCLE 255 ON READER-SERVICE CARD



SEND FOR NEW
FREE CATALOG ON
KENDALL
and
GOVERNAIRE

Catalog gives performance and other data on 18 models of precision pneumatic pressure regulators. (pipe sizes ¼ to ¾ NPT)



STRATOS
A DIVISION OF FAIRCHILD ENGINE & AIRPLANE CORPORATION
INDUSTRIAL PRODUCTS BRANCH
West Babylon, L. I., N. Y.

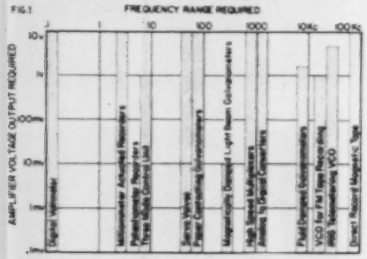
CIRCLE 112 ON READER-SERVICE CARD

D-C AMPLIFIER EVALUATION *number 4 in a series*

AMPLIFIER GAIN

The voltage amplification or gain of a d-c amplifier is the dimensionless ratio of the output voltage to the input voltage, assuming operation in the linear portion of the amplification characteristic, and at a specified frequency, usually 0 cps. The curve of amplifier gain vs. frequency of the input signal is termed "frequency response".

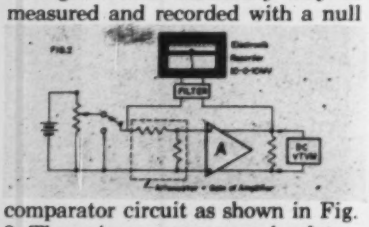
The gain factor is of little value to the user unless the minimum full scale input or the maximum linear full scale output is known. As part of a system, the desired amplifier output level is determined by the load characteristics. Typical amplifier loads are shown in Fig. 1.



If the output requirement is known, the gain needed to amplify the input to give full scale output can be determined. However, power requirements must also be considered. If the load resistance is sufficiently low the maximum output current is reached before maximum voltage output, and the amplifier will saturate with further increases in input signal. The value of the voltage across the load with maximum rated current is then used to determine gain.

Gain Stability vs. Gain Accuracy

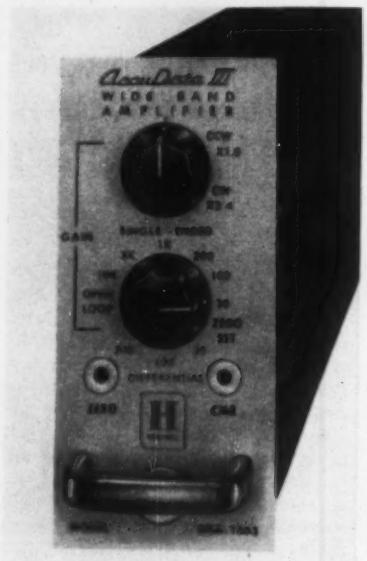
The errors in gain caused by external factors such as ambient temperature, line voltage, and component aging are termed gain instability. Gain accuracy is the allowable tolerance between gain settings and actual gain. Gain instability may be measured and recorded with a null



comparator circuit as shown in Fig. 2. The gain accuracy may be determined by substituting in this circuit a precision attenuator. For information on gain stability measurement write for application notes BEAN 122.

AccuData III has Gain of 34,000

Full scale output of the new Honeywell AccuData III d-c amplifier is 10 volts, 25 milliamps up to 20 kc. Minimum full scale input is 0.3 mv single-ended, a voltage gain of 34,000. Its gain instability is ± 0.01% for a ± 10° F. temperature range. Gain setting accuracy with the fine gain control in the CCW position is ± 0.2% for differential or single-ended connected gains up to 1000, and ± 0.5% for



gains in the 3000 to 34,000 range. Eleven different gain positions including zero and an open loop position for operational amplifier connections are provided. Other features of this amplifier include high common-mode rejection, very low noise and drift, and unparalleled linearity. Write for Bulletin BS DISA-3 to Minneapolis-Honeywell, Boston Division, Dept. 50, 40 Life Street, Boston 35, Massachusetts.

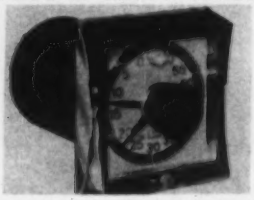
Honeywell

First in Control

SINCE 1885

CIRCLE 113 ON READER-SERVICE CARD

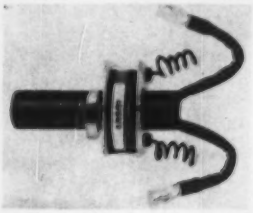
PLUG-IN RESET TIMER



New Plug-In Bulletin-125 Cycl-Flex Reset Timer is furnished complete with its own plug-in case. Timer easily can be removed and replaced. Timer contains four separate and independent load contacts, two of which are instantaneous and can be used as relays. Two others are time delay relay contacts which feature built-in adjustment to provide for an additional timed differential at the end of the time interval.—*Eagle Signal Co., a div. of the Gamewell Co., 202-20th St., Moline, Ill.*

CIRCLE 256 ON READER-SERVICE CARD

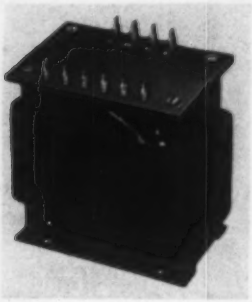
MERCURY PLUNGER RELAY



New Ebert-100 Mercury Plunger Relay is claimed to be the first 100-amp/115-vac relay capable of handling a full 12-kw tungsten lamp load. Featuring mercury-to-mercury contacts hermetically sealed in tempered nonex and encapsulated in bakelite for contamination-free long life, an inert gas atmosphere quenches arcs for cool running operation.—*Ebert Electronics Corp., 212-32A Jamaica Ave., Queens Village, N. Y.*

CIRCLE 257 ON READER-SERVICE CARD

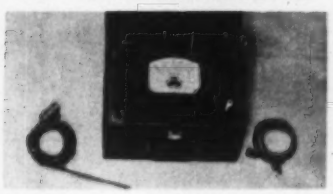
500-VA TRANSFORMER



New 60-cycle/500-va Constant Voltage Transformer with an input of 95 to 130 v and an output of 115 v has a line regulation of ±1½%. Can be hermetically sealed for military applications.—*Freed Transformer Co., Inc., 1718 Weirfield St., Brooklyn (Ridgewood) 27, N. Y.*

CIRCLE 258 ON READER-SERVICE CARD

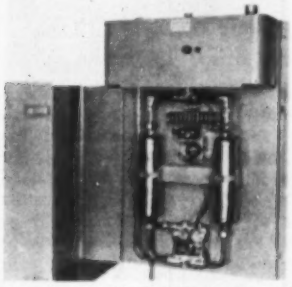
HOT WIRE ANEMOMETER



New Hot Wire Anemometer, Model 54A1, which provides a continuous accurate measurement of the mass velocity of air or other gases, has an indicator and also an external output for chart recorder or oscilloscope. It utilizes a completely transistorized circuit to maintain constant the resistance ratio of a hot and a cold filament by means of a feedback amplifier. Standard range is 0-4000 ft/min on three scales. Its frequency response is dc to 1000 cps; accuracy is 5% of the reading. Powered by rechargeable nickel-cadmium batteries, it is completely portable.—*Flow Corp., 85 Mystic St., Arlington, Mass.*

CIRCLE 259 ON READER-SERVICE CARD

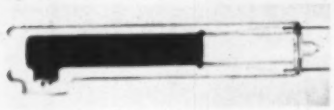
HEATERLESS AIR DRYER



New Model MPS-5 Heaterless Dryer dries up to 3.5 scfm of compressed air to a dew point of −40°F or lower. Larger flows are obtainable if higher effluent dew points are satisfactory. It is a dual-tower unit, which requires no heat source. Bulletin MPS-5 contains details.—*Kahn & Co., Inc., Box 516, Hartford 1, Conn.*

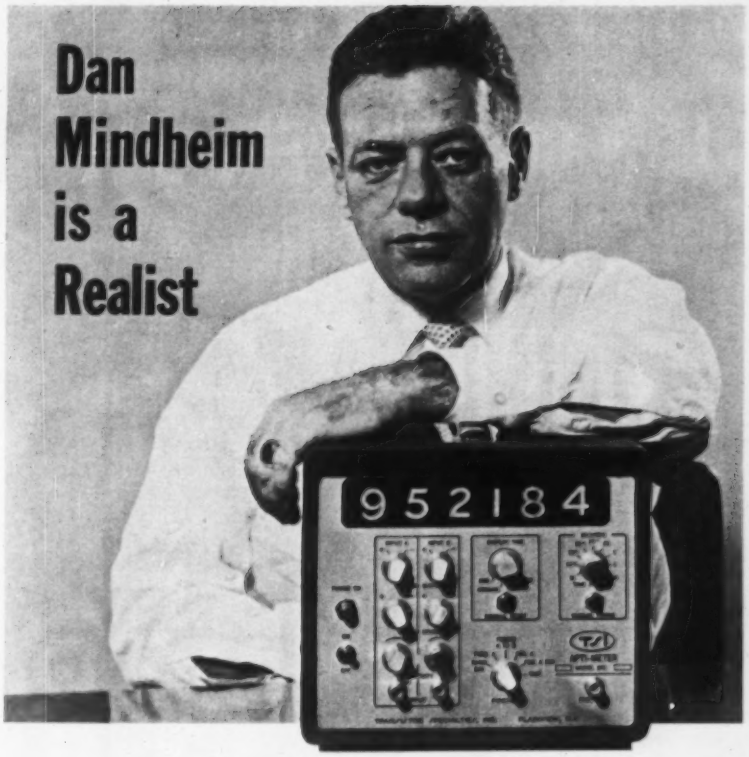
CIRCLE 260 ON READER-SERVICE CARD

COOLED-CELL PbS DETECTOR



New high-performance dewar-mounted IR Dectectors (immediately available from stock) contain lead-sulfide elements, designed for operation at room temperature and cooled, to −196°C, with special response out to 4.5μ mounted in several dewar configurations, all with fire-sealed sapphire windows. The detector sensitive area will be varied in width and length from 0.010" to 0.200", according to customer specifications.— *Infrared Industries, Inc., Box 42, Waltham 54, Mass.*

CIRCLE 261 ON READER-SERVICE CARD



. . . he DREW THE LINE at 1MC!

The most difficult task facing an engineering executive is to strike a **sensible compromise** between the ambitions of his development staff and the needs of the market. No one knows that better than Dan Mindheim, President of TSI. Twelve years of product development (including nine major patents) give him the designer's point of view — but ten years of management experience temper that attitude.

In determining the specifications for our Model 361 **solid-state** APTI®-METER,* for example, he drew the line at 1MC. "95% of all counter-timer applications fall below 1MC," he said. "Let's concentrate on optimizing **flexibility, reliability,** and **portability.** That's what engineers want—at a **sensible** price."

Dan was right. The 361 is selling like . . . well, like **the world's best solid-state 1MC Counter-Timer,** which it is. Frankly, we're hard-pressed to maintain 30-day delivery. The same for its 3½" rack twin, the 361-R.

Care to add to our production headaches? Send for the APTI®-METER bulletin. Buy a few — our development group will forgive you.

**APTI®-METER is our registered trade-mark for an ACTIONS-PER-TIME-INTERVAL meter. Model 361 counts from 0-1MC, has 0.3ppm/week stability, IN-LINE NIXIE READOUT, and identical-twin, high-impedance, high sensitivity amplifiers. Unbelievable versatility, light as a feather, tiny, yet the sensible-compromise price is only $1645.*

TSI

TRANSISTOR SPECIALTIES
INCORPORATED

Sophisticated Digital Instrumentation

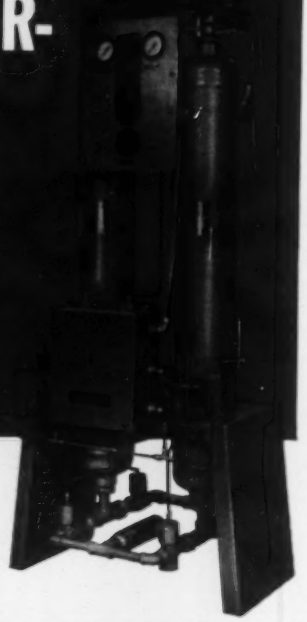
TERMINAL DRIVE, PLAINVIEW, NEW YORK • WELLS 5-8700

CIRCLE 114 ON READER-SERVICE CARD

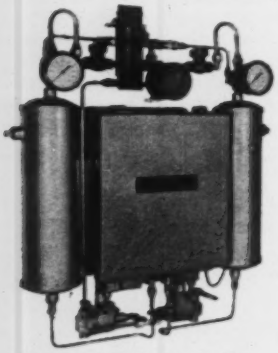
LOW COST, DEPENDABLE INSTRUMENT AIR-

TRINITY

Heat-Les

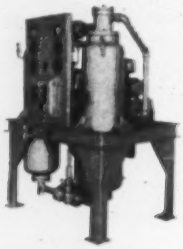


Increase dependability and accuracy of measurement and control in your system by specifying a dependable Trinity Heat-Les Dryer. These amazing dryers, operating on a principle so simple, yet so efficient, are establishing unparalleled operating records in over a thousand installations.



Trinity Heat-Les Dryers are available in standard models ranging from 2 SCFM to 5000 SCFM. Units up to 200 SCFM are available from stock

- ★ Low initial cost
- ★ Completely eliminates costly electric or steam heaters
- ★ No increase in effluent gas temperature
- ★ Low installation costs
- ★ Low operating and maintenance costs
- ★ Built-in safety system provides dry air for extended period after power failure.



ALSO HEAT-REACTIVATED DRYERS

Trinity also offers a complete range of capacities in heat-reactivated type dryers of an advanced design, offering the greatest economies and performance for this type dryer... **WRITE FOR COMPLETE TRINITY DRYER AND ACCESSORY TECHNICAL MANUALS...**

TRINITY **World leader in dry gas/air systems**

Heat-Les Dryers • Heat-reactivated Dryers
Thermocouples and Thermowells

TRINITY EQUIPMENT CORPORATION, CORTLAND, NEW YORK

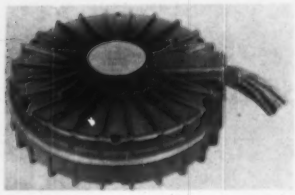
CIRCLE 115 ON READER-SERVICE CARD

SENSITIVE INDICATOR LAMP

New transistorized filament-lamp Indicator, the Minisig R-342, operates directly from T-Series digital plug-in circuit modules. Unit includes a self-contained transistorized switch designed to turn the lamp on at −3v (logical input "1"), and to turn the lamp off at −11v (logical input "0"). Idling current is 2 ma at −12 v and 2 ma at +12 v. Lamp glows brightly when Logic "1" is applied. Power drain is 0.65 ma at −2 v and 42 ma at +12 v.—*Engineered Electronics Co., 1441 E. Chestnut Ave., Santa Ana, Calif.*

CIRCLE 262 ON READER-SERVICE CARD

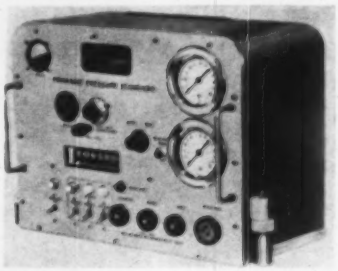
DISC MEMORY



New line of rotating Magnetic Memories includes computer component, laboratory test model, or a console model completed with companion electronic circuits. Typical characteristics of Model UMM-3A are an 8" disc, a speed of 1800 rpm, 50 heads, write current of 30 to 60 ma peak to peak, read voltage of 75 mv peak to peak, no dropouts, less than 15% modulation pattern, capacity of 400,000 bits, and life of over 5,000 hr.—*Genesys, 10131 National Blvd., Los Angeles 34, Calif.*

CIRCLE 263 ON READER-SERVICE CARD

PRESSURE STANDARD



New Primary Pressure Standard utilizes a simple air-dead-weight tester to provide direct readout of pressure over a prescribed range. Typical accuracy is 1/50% of reading over the range of 0.4 to 250 psi including all errors.—*Wallace O. Leonard, Inc., 373 South Fair Oaks Ave., Pasadena, Calif.*

CIRCLE 264 ON READER-SERVICE CARD

SHOCK PROTECTION

New Model 707 twin-rack's Floatation System, which literally keeps equipment "riding-on-air" thus prolonging the life of any wheeled instrumentation, accepts two 19" panels in a butt arrangement (as shown) or a single 38-inch panel on either side. —*Escortronics, 7000 Vine St., La Grange, Ill.*

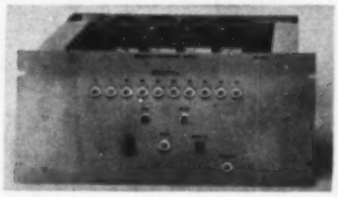
CIRCLE 265 ON READER-SERVICE CARD

SHEARABLE DISC VALVE

New Shearable Disc Valve has a non-aging metallic disc that provides zero leakage in the pre-sheared condition. Actuation is rapid either by pneumatic, hydraulic, or pressure cartridge (squib) action. In the open position, there is full flow with minimum pressure drop. Upon reclosure of the valve, after shearing, leakage is exceptionally low.—*B. H. Hadley, Inc., 1247 So. Garey Ave., Pomona, Calif.*

CIRCLE 266 ON READER-SERVICE CARD

PROGRAMMED SUPPLY



New Model 850 Programmed Millivolt Calibration Reference Supply delivers preselected precise calibration voltages over the range 0-0.1 v from a constant impedance output of only 0.01 ohm. Absolute accuracy is 0.02% for line voltage variations of ±10% over the temperature range from 40°F to 125°F. Tracking accuracy is better than 0.01%. The chopper stabilized supply maintains a 30-day stability of better than 0.005%.—*Owen Labs., Inc., 55 Beacon Pl., Pasadena, Calif.*

CIRCLE 267 ON READER-SERVICE CARD

Heinemann can give you any set delay from a quarter-second wink to a two-minute yawn, all wrapped up in a relay no bigger than a healthy ice cube. Called the Type A Silic-O-Netic Relay, this three-ounce time-delay unit offers S.P.D.T. or D.P.D.T. switching, with up to three amps' contact capacity. All of which is pretty good, but the real clincher is the continuous-duty coil. It permits the relay to be energized continuously, to serve as a load relay, too. This eliminates the need for auxiliary lock-in circuits. Result: substantial savings in space, wire, solder—and dollars. Bulletin 5003 gives detailed specifications; a copy is yours, of course, for the asking.

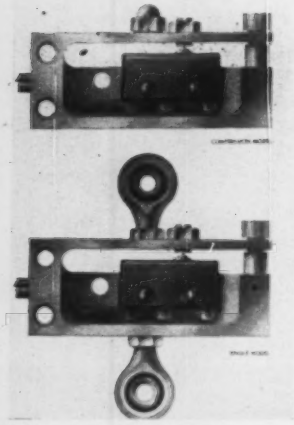
HEINEMANN ELECTRIC COMPANY

160 PLUM STREET TRENTON 2, NEW JERSEY

2175

CIRCLE 116 ON READER-SERVICE CARD

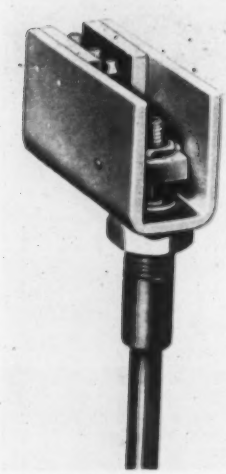
FORCE CONTROL SWITCH



New subminiature (approximately 1⅞" x ⅞" x 1") Force Control Switches are for automatic starting and stopping of motors, activating of equipment in sequence, tripping of relays, etc. and weigh only ¼ oz and have an accuracy within ½ of 1%. Three different capacities are offered: 0-5 lb, 0-30 lb, 0-100 lb. Bulletin 49-E gives details.—*W. C. Dillon & Co., Inc.*, 14620 *Keswick St., Van Nuys, Calif.*

CIRCLE 268 ON READER-SERVICE CARD

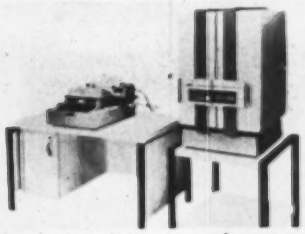
THERMOSTAT



New Model S-1S Thermostat is a miniature-size, differential-expansion-type control having 8 standard ranges up to 1150°F. It incorporates a snap-action switch rated 5 amp/125-250 vac, 30 amp/30 vdc, and is available in the open style or with a NEMA-1-type enclosure. Details in Bulletin 122.—*Burling Instrument Co., Chatham, N. J.*

CIRCLE 269 ON READER-SERVICE CARD

DIGITAL COMPUTER



New ultra-fast general purpose, Digital Computer, Model PB250, combines a large, expandable memory and a versatile command structure with computing speed in the microsecond range. Until now, these combined features were available only in the largest computers, priced over $200,000. The PB 250 is priced at $30,000. Qualified for either on-line or off-line applications its outstanding features include: (1) Microsecond speed, (2) expandable memory: 1,808 words expandable to 15,888 words internally. (3) versatile command structure: 46 commands including double precision operation, block transfer, Gray to binary conversion. (4) simple programming achieved by single-address instructions, command indexing, and automatic double precision operation, etc.—*Packard Bell Computer Corp.*, 1905 *Armacost Ave., Los Angeles 25, Calif.*

CIRCLE 270 ON READER-SERVICE CARD

PARIS - MAY 9 - 17 1961

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International Exhibition
MEASUREMENT - CONTROL
REGULATION - AUTOMATION

OVER THE PAST 20 YEARS.

Physics Research has played a leading role in the rapid development of many of our Industries,
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From May 9th. to May 17th. 1961, the NATIONAL CENTRE FOR INDUSTRY AND TECHNIQUES will be holding a fantastic Exhibition for International Apparatus and Control, Measure, Readjustment and Automation methods, showing the importance of all these improvements for the different techniques in Industry, Laboratories and Research Centres.
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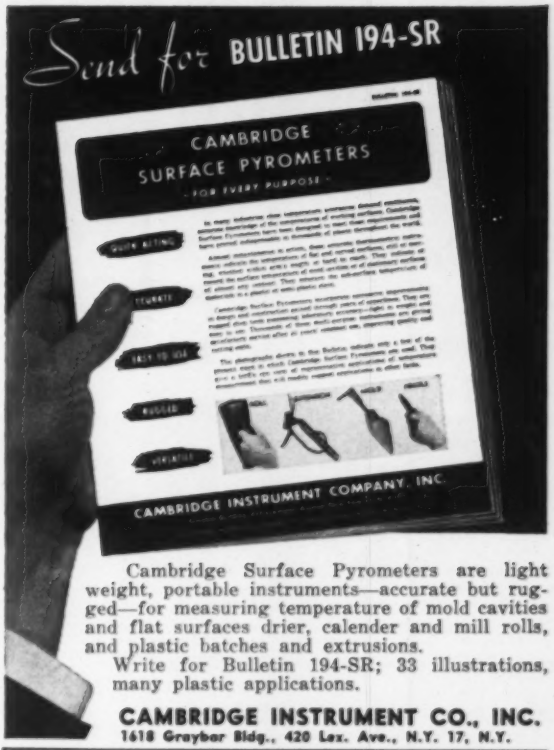


Cambridge Surface Pyrometers are light weight, portable instruments—accurate but rugged—for measuring temperature of mold cavities and flat surfaces drier, calender and mill rolls, and plastic batches and extrusions.

Write for Bulletin 194-SR; 33 illustrations, many plastic applications.

CAMBRIDGE INSTRUMENT CO., INC.
1618 Graybar Bldg., 420 Lex. Ave., N.Y. 17, N.Y.

THEY HELP SAVE MONEY AND MAKE BETTER PLASTICS

CIRCLE 118 ON READER-SERVICE CARD

READ any surface temperature in 3 seconds with Alnor® PYROCON®

Particularly, in the lower temperature range, the Alnor Pyrocon has extreme accuracy unmatched by any other instrument of its type.

Alnor offers the widest variety of interchangeable tips for reading temperatures on metallic or non-metallic, flat, curved, revolving or stationary surfaces as well as semi fluid materials, plastics, liquids, molten or soft metals, dies, rubber, waxes and many other surface or subsurface materials.

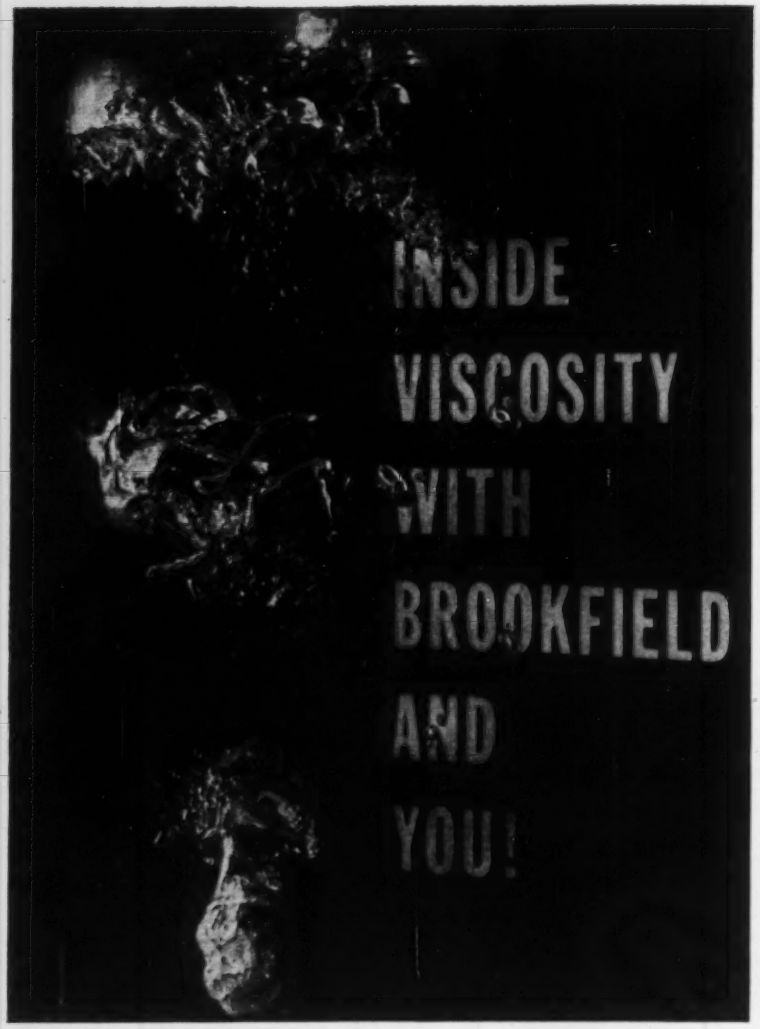
The Pyrocon is a compact, rugged instrument built with the highest standards of accuracy and dependability as well as speed in reading.

Eight models with temperature ranges from 0—300°F. to 0—2000° F.
Write for bulletin 4257.

Alnor INSTRUMENTS

ALNOR INSTRUMENT CO.
Division of
Illinois Testing Laboratories, Inc.
Rm. 518, 420 N. LaSalle St., Chicago 10, Ill.

CIRCLE 119 ON READER-SERVICE CARD



Right to the heart of this vital product dimension . . . that's where Brookfield can take you. Consider this an invitation to ask Brookfield to bring you up to date on how viscosity control, through Brookfield instrumentation, can be profitably applied to your processes. Viscosity measurement, recording and control can now be accomplished automatically for practically any fluid material. Low investment Brookfield portable and process-mounted instrumentation now plays a major role in practically every phase of chemical processing and research.

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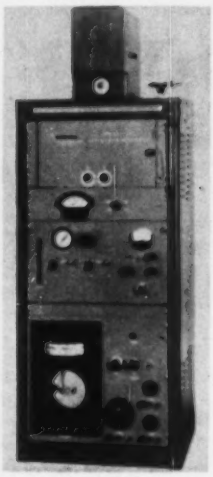
THE WORLD'S STANDARD FOR VISCOSITY MEASUREMENT AND CONTROL

Brookfield

ENGINEERING LABORATORIES, INCORPORATED
STOUGHTON 116, MASSACHUSETTS

CIRCLE 120 ON READER-SERVICE CARD

GAS CHROMATOGRAPH



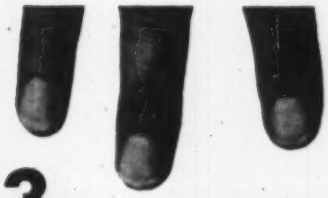
New programmed-temperature Gas Chromatograph, Model 17, permits column operation from ambient to 500°C. Two symmetrically heated columns are used; one column for the analysis, and the other column discharges through the reference detector for column vapor pressure compensation. The column temperature is programmed by the use of a cam-programmed temperature controller. Spec Sheet gives details.—*Loe Engineering Co. 237 North Fair Oaks, Pasadena, Calif.*

CIRCLE 271 ON READER-SERVICE CARD

PURGED PITOT TUBE

New Purge Clean-Out Pitot Tube features a blow out system that utilizes compressed air to clear its total pressure probe and static pressure element of obstructions. A 3-way valve prevents direction of blowout pressure toward the gage manometer. Five tube sizes are available; nominal insertion lengths of 3", 6", 12", 18", and 24", suitable for ducts with 6", 12", 36" and 48" dia.—*F. W. Dwyer Mfg. Co., Dept. 1A-5, Box 737, Michigan City, Ind.*

CIRCLE 272 ON READER-SERVICE CARD



3 Reasons Why

Robbins VALVES Are the Most Economical You Can Buy

1. The only valves that can be completely serviced in less than 1 minute from the front of mounting panel without removing the valve from the line!

To service a Robbins Metering & Shut-Off Valve it is only necessary to remove the handle, loosen locknut and remove barrel assembly . . . all accomplished from the front of the panel . . . no need to disturb the line connections!

2. Single barrel assembly!

For both civilian and military installations the single barrel assembly design and construction features (barrel, spindle, spindle seals, barrel seals and seat in one unit, cleaned, lubricated, sealed for oxygen service) mean practically instantaneous renewal of service without disconnecting any plumbing.

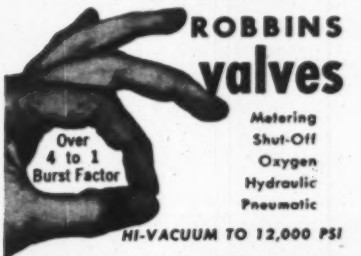
3. As many as 5000 cycles before requiring servicing!

Many Robbins Metering Valves . . . in constant use on an 8-hour a day basis for three years . . . have never required servicing, lubrication, or any parts replaced!

...And the Most Reliable!

Precision made and tested. Design capabilities, manufacturing procedures, and quality control operations at Robbins Aviation are all directed toward one objective . . . to produce a valve of the highest quality that will provide the user with the greatest reliability and the greatest economy over many years of service.

All Valves LOX Cleaned and Packaged . . . Ready for Instant Use



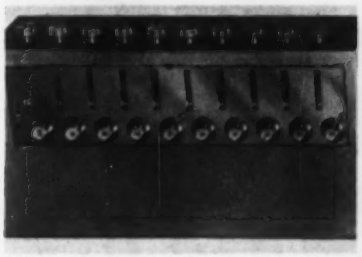
ROBBINS Aviation Inc.

Write today for complete color catalog and valve technical information

2350 E. 38th St., Los Angeles 58, Calif.
LUdlow 9-5221

CIRCLE 121 ON READER-SERVICE CARD

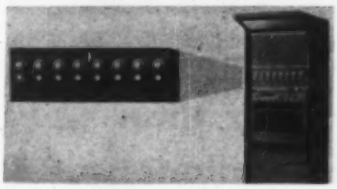
TIME UTILIZATION METER PANEL



New Time Utilization Meter Panel shows with pilot lights and time accumulation figures the productive operations of ten individual machines, processes or operations. Each individual machine or operation is electrically connected to the meters to show only productive (not merely motor idling) time. Features include six-digit, resettable figure wheels, readable to hours and tenths hours, tenths and hundredths; or minutes and tenths. Bulletin gives details.—*Gorrell & Gorrell, 336 Old Hook Rd., Westwood, N. J.*

CIRCLE 273 ON READER-SERVICE CARD

DIRECT WRITING OSCILLOGRAPH



New Type RD Dynograph, specifically designed for low and medium gain applications, is completely transistorized. It features sensitivity of 10 mv/cm to 100 v/cm, drift of 0.2 mv/hr, and interchangeable recording media (ink or electric curvilinear; heat or electric restilinear). One to eight channels are standard with Type 504A rack-mounted paper drive; up to 24 on other mountings.—*Offner Electronics Inc., 3900 River Rd., Schiller Park, Ill.*

CIRCLE 274 ON READER-SERVICE CARD

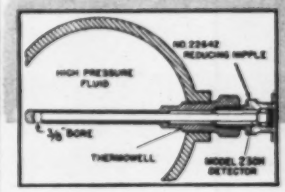
MAGNETIC SHIELDING CANS

New line of Netic and Co-Netic Magnetic Shielding Cans for choppers, miniature tubes, transformers, and other nominally sized electronic components is offered at 30% cost savings in production quantities over previous prices due to radically new manufacturing techniques. The finished shields are comparable to drawn types in shielding effectiveness.—*Magnetic Shield Div., Perfection Mica Co., 1322 N. Elston Ave., Chicago 22, Ill.*

CIRCLE 275 ON READER-SERVICE CARD

EDISON

RTD 230N DETECTS LIQUID AND GAS TEMPERATURES from −100° to +600°F



This patented construction Resistance Temperature Detector is a low-cost stem-sensitive, general purpose detector for fast, precise temperature measurement and control in industrial processes. Hermetically sealed RTD 230N measures the temperature of steam, water and oil up to 600°F. For complete information, write for Reference Data Sheet 1045A-4.

SPECIFICATIONS:

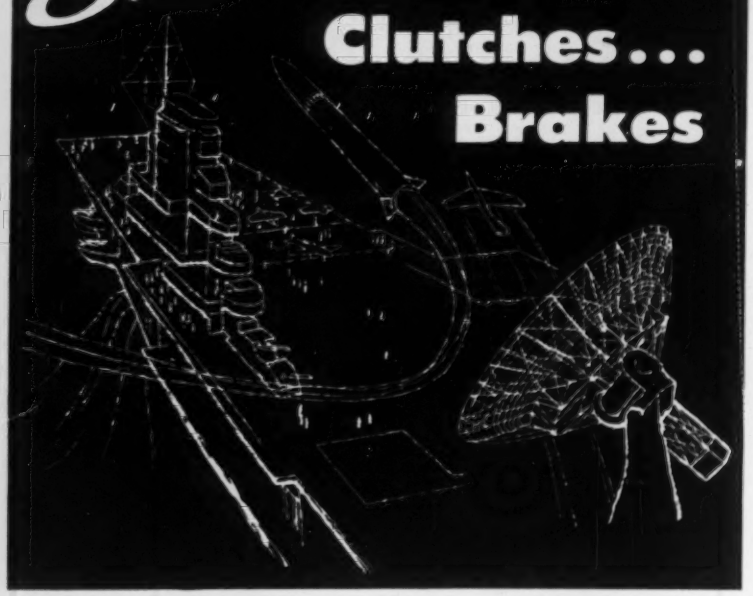
Temperature Resistance Characteristic: No. 7
Time Constant in Agitated Water: 2 sec.
Maximum Current in Air: 0.015 amps; in Water: 0.025 amps
Maximum Pressure: 200 psi

THOMAS A. EDISON INDUSTRIES
INSTRUMENT DIVISION
West Orange, New Jersey

McGRAW EDISON

CIRCLE 122 ON READER-SERVICE CARD

Stearns electro-magnetic Clutches... Brakes



. . . designed for tomorrow's requirements rather than yesterday's applications!

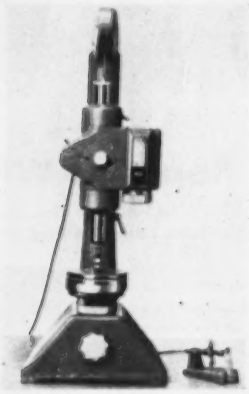
Whatever the requirements — for missiles or machines — for computers or conveyors — for rockets or rolling mills — there's a Stearns Clutch, Brake, or Clutch-Brake designed, tested and in production for that application . . . right now! Stearns *Standard Line* covers the most complete range available anywhere . . . from *complete lines* of tiny-but-rugged Miniatures — up to the heavy-duty, hi-torque units used with ball mills and steel mill equipment. *"Designed for Tomorrow's Requirements"* signifies: 1. Prompt availability of fully assembled, tested units. 2. Higher torques in less space, with less weight — while maintaining up to 3 times the friction lining area of competitive units. These factors alone insure delivery *WHEN* you want it — at lower shipping costs . . . install them faster, easier . . . units that will operate more quietly, efficiently, smoothly — with less maintenance, l-o-n-g-e-r, under *ALL* conditions. Proof . . . over 40 years of steady growth in just this one field — Clutches, Brakes.

For solutions to YOUR brake and clutch problems, call the Stearns representative in your vicinity. Or write, stating your specific requirements, directly to . . .

Stearns ELECTRIC CORPORATION
120 NORTH BROADWAY
MILWAUKEE 2, WISCONSIN

CIRCLE 123 ON READER-SERVICE CARD

DIMENSIONAL GAGE



New Vertical Gage by Leitz has a direct measuring range between 0 and 4" from a Master Glass Scale. The scale interval of 0.050" is subdivided by an optical micrometer in 0.000025". All readings are on projection screens and so organized that they are absolutely fool-proof.—*Opto-Metric Tools, Inc., 137 Varick St., New York 13, N. Y.*

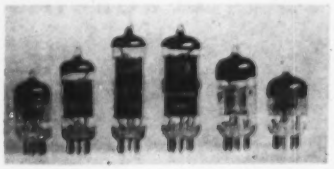
CIRCLE 276 ON READER-SERVICE CARD

DEHYDRATION CARTRIDGES

New instrument-type Dehydrator Units are designed for connection directly into the system line to protect delicate sealed instruments, relays, sparking contracts, and other similar components from moisture, contamination, oil vapor, fuel vapor and corrosive or explosive gases. Fiber glass pads control downstream particle size to less than 10M.—*Robbins Aviation, Inc., of 2350 East 38th St., Los Angeles, Calif.*

CIRCLE 277 ON READER-SERVICE CARD

MINI THERMAL ANALOG TUBES

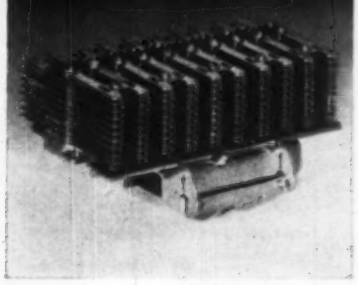


New line of Thermions, Thermal Analog Tubes, representing all miniature size classes of electron tubes, allows performance of guided thermal design of electronic packages and precise determination of cooling requirements under actually simulated operating conditions. Subminiature thermions are also available.—*Rescon Electronics Corp., 151 Bear Hill Rd., Route 128, Waltham 54, Mass.*

CIRCLE 278 ON READER-SERVICE CARD

STROMBERG-CARLSON

"BB" SERIES RELAYS



For your automation ...computing...control circuit applications...

"TELEPHONE QUALITY"

at an ordinary price

To meet your needs for precision and durability in automation, computing and control circuitry, here is *telephone quality* at an ordinary price.

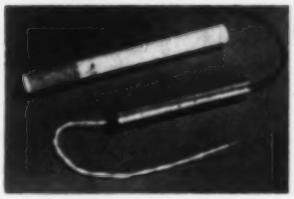
The "BB" Series Relay accommodates up to 100 Form A spring combinations. It incorporates such important advantages as twin contacts, knife-edge pivot and special frame-armature construction. Like all Stromberg-Carlson relays, it is built to operate under extreme ranges of temperature and humidity. *Prompt delivery is available on all orders.*

For details, in Atlanta call TRinity 5-7467; Chicago: STate 2-4235; Kansas City: HArrison 1-6618; Rochester: HUbbard 2-2200; San Francisco: OXford 7-3630. Or write to Telecommunication Industrial Sales, 113 Carlson Rd., Rochester 3, N. Y.

STROMBERG-CARLSON
A DIVISION OF
GENERAL DYNAMICS

CIRCLE 124 ON READER-SERVICE CARD

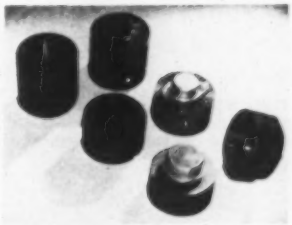
ELECTRO-OPTICAL RELAY



New Raysistor unit is an Electro-optical Relay with a conductance on-off ratio of 1,000,000 to 1 and capable of speeds up to 100 operations/sec. It includes a light source in the control end, which, when excited, actuates a photo-conductor in the signal end, allowing either a-c or d-c information to pass. One of its outstanding characteristics is the ability to switch without introducing transients in the signal circuit. When used as a potentiometer it is absolutely free of contact noise.—*Raytheon Co., Industrial Components Div., Newton 58, Mass.*

CIRCLE 279 ON READER-SERVICE CARD

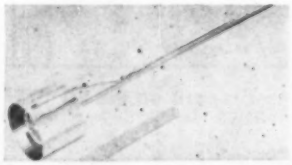
HEAT SINKS



New types of heat radiators, or Heat Sinks, dissipate heat rapidly by radiating surfaces of 35 to 65 sq-in which are machined to rigid specifications, giving low thermal resistance. —*Relco Products, 5594 East Jefferson Ave., Denver 10, Colo.*

CIRCLE 280 ON READER-SERVICE CARD

PRESSURE CALIBRATION

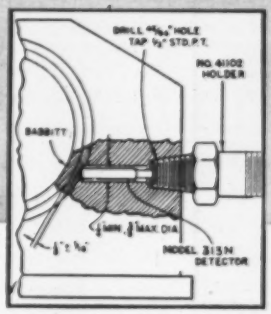


New Reference Pressure Cell consisting of a pressure storage chamber, a diaphragm and a sensitive switch uses a new principle of referencing the unknown pressure against a previously "stored" and calibrated pressure. Accuracy can be better than 0.001" Hg +0.003% of calibrated value. Sensitivity is such that a fraction of a mil of Hg gives positive indication. Details in Bulletin 46027.—*Rosemount Engineering Co., 4900 West 78th St., Minneapolis 24, Minn.*

CIRCLE 281 ON READER-SERVICE CARD

EDISON

RTD 313N MEASURES METAL TEMPERATURES from −100° to +600°F



Because it has two concentric sensing elements in its tip, this Resistance Temperature Detector is essentially two detectors in one housing. Designed to measure such metals as machinery bearings, its independent elements can be used to operate individual indicators, monitors, recorders, controls or two instruments in different locations. Extension tubes available up to 10 feet long. May be used in thermowells with ⅜" bore. For complete information, write for Reference Data Sheet 1045A-8.

SPECIFICATIONS:

Temperature Resistance Characteristic: No. 7
Time Constant in Agitated Water: 5.0 sec.
Maximum Current in Air: .015 amps; in Water: .025 amps
Maximum Pressure: 15 psi

THOMAS A. EDISON INDUSTRIES
INSTRUMENT DIVISION
West Orange, New Jersey
McGRAW EDISON

CIRCLE 125 ON READER-SERVICE CARD

THE ALL NEW RD 103, SOLID STATE RELAY FROM U. S. RELAY-ELECTRONICS!

Actually Has No Moving Parts!

ACTUAL SIZE

From the Research and development Center of U.S. Relay-Electronics comes the RD 103, a solid state relay which offers *ULTRA SENSITIVE* low power input of only 1½ milliwatts. The RD 103 is engineered to withstand the critical accumulative environmental conditions which usually cause failure of the electro-mechanical type relays.

The RD 103 is built to operate at more than one million cycles at full rated load of 200 milliamps at 30 volts and offers the rugged dependability required in missiles and aircraft applications.

If you have an application which requires a current sensitive relay, check the following specifications

Sensitivity:	1.5 Milliwatts
Output power:	6 watts max.
Input power nominal:	3 milliwatts approximately. 500 microamps at 2.5 volts
Ambient Temperature:	—65°C to +71°C
Minimum operating cycles:	unlimited
Duty:	continuous
Vibration:	in excess of 30 G's to 2000 cps
Shock:	100 G's
Weight:	1⅓ ounces

For further information and certified test reports on the RD 103 Solid State Relay write:

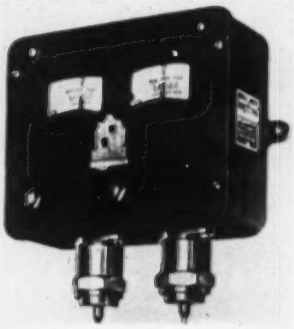
USRE

U. S. RELAY-ELECTRONICS

717 No. Coney Ave. Azusa, California
a division of A·S·R Products Company.

CIRCLE 126 ON READER-SERVICE CARD

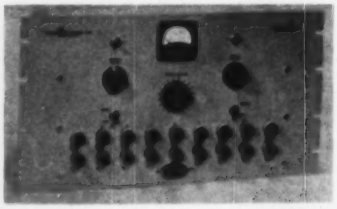
DUAL TEMP CONTROLLER



New Cast-a-trol, a compact Dual Indicating Controller for temperatures of both the type metal melting pot and the "mouthpiece" which directs the metal into molds to form lines of type, is housed in a single case for convenient mounting.—*Partlow Corp., 536 Campion Rd., New Hartford, N. Y.*

CIRCLE 282 ON READER-SERVICE CARD

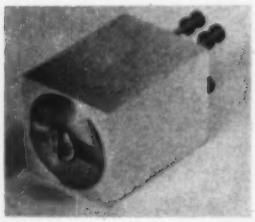
TC CONTROL UNIT



New Model TC 2R Control Unit, combined with reference junction and any galvanometer type oscillograph, provides a complete system for the simultaneous recording of independent channels of temperature information. Available in 12- and 18-channel capacity models.—*Pace Engineering Co., 13035 Saticoy St., North Hollywood, Calif.*

CIRCLE 283 ON READER-SERVICE CARD

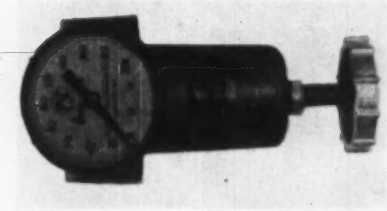
ACCELERATION-SENSITIVE SWITCH



New Model AS-4 Switch is responsive to acceleration in one direction along a single axis. Resetting is by means of high acceleration in the opposite direction or by manual reset. Accuracy is under 0.2 G; response time is less than 50 msec.—*Eastern Technical Associates, Inc., Main St., North Acton, Mass.*

CIRCLE 284 ON READER-SERVICE CARD

PRESSURE REGULATOR



New Air Pressure Regulator for high and low pressure ranges, provided by two sets of springs, assures closely-regulated pressure regardless of variations in the flow rate over the full range from 5 to 125 psig. —*Perfecting Service Co., 332 Atando Ave., Charlotte, N. C.*

CIRCLE 285 ON READER-SERVICE CARD

8-AMP POWER SUPPLY

New Model RP-10, completely transistorized, regulated, 8-amp Power Supply is especially designed for computer applications. It powers 320 LE-10 Logical Element T-PAC's operating continuously at one megacycle or 640 operating at 50% duty cycle. A special circuit is included for the protection of the transistors in the load circuit.—*Computer Control Co., Inc., 983 Concord St., Framingham, Mass.*

CIRCLE 286 ON READER-SERVICE CARD

VACUUM RECORDER

New Vacuum Recorder is made in two ranges: 0 to 25, and 0 to 5000 m. Designed for use with the ASCO Pirani-type gage, it operates at one inch/hr. A 63-ft chart roll records for 31 days. Marking process is entirely dry, on special pressure-sensitive paper. Rated accuracy is 2% of full scale. Available for portable use or with brackets for panel mounting. —*Arthur F. Smith, Inc., 311 Alexander St., Rochester 4, N. Y.*

CIRCLE 287 ON READER-SERVICE CARD

New...from MARSH!

Conduit-type Master-mite. Grommet-type also available.

Small Solenoid Valves that fill a BIG Order

Designed to meet the need for positive-acting tight-seating valves for use on wide variety of media, including oxygen, hydrogen, acetylene, etc.

Two Types:
Conduit type and grommet type. Port sizes 1/8" and 1/4" NPT.

Ten orifice sizes: 3/64" through 1/4".

Wide range of voltages:
Standard with 115 V. A. C. but also available in 12, 24, 208, 230, 460 V. A. C.

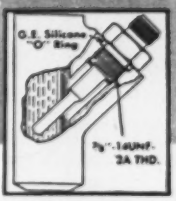
Pressure to 540 psi.
Small, but with more strength in the Marsh manner. Coils never overheat. Entire assembly leak tight. Remarkably quiet operation. Cleanable without breaking connections. Used in any position. Bodies either brass bar stock or 18-8 stainless steel. All moving parts stainless. Underwriters' approved for use on oxygen and hydrogen and as safety valves.

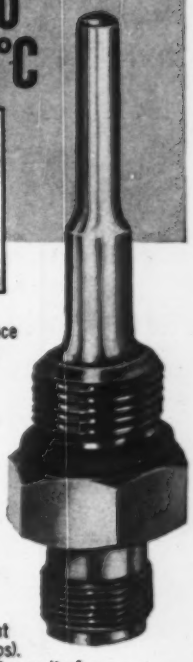
Write for new bulletin

MARSH INSTRUMENT COMPANY
Dept. 42, Skokie, Illinois
Division of Colorado Oil and Gas Corporation
Marsh Instrument & Valve Co., (Canada) Ltd., 8407 103rd St., Edmonton, Alberta, Canada, Houston Branch Plant, 1121 Rothwell St., Sect. 15, Houston, Texas.

CIRCLE 127 ON READER-SERVICE CARD

EDISON
RTD 249N90-1 MEASURES LIQUID TEMPERATURES UNDER NUCLEAR RADIATION from –70° to +200°C





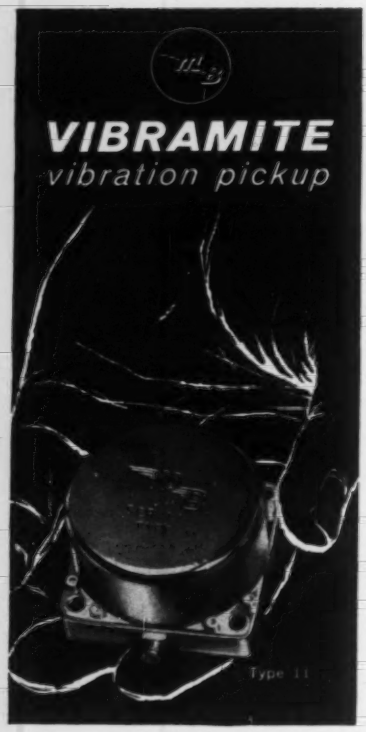
This stem-sensitive, fast-response Resistance Temperature Detector is specifically constructed to meet rigorous environmental operating conditions in turbulent liquids under nuclear radiation. Absolutely water-tight even under pressures to 200 psi while subject to vibration and acceleration to 100 g's under resonant frequency (or 2000 cps). For complete information, write for Reference Data Sheet 1045A-7.

SPECIFICATIONS:

Temperature Resistance Characteristic: No. 1
Time Constant in Agitated Water: 1.5 sec.
Resistance Tolerance: ± 0.5%
Maximum Current in Air: 0.015 amps; in Water: 0.020 amps
Withstands: Radiation level of 500 rad/hr. from 0°C to +170°C
Radiation exposure of 5 x 10^9 rad total of 1 MEV average
Gamma radiation at temperatures of 125°C to 150°C

THOMAS A.
EDISON INDUSTRIES
INSTRUMENT DIVISION
West Orange, New Jersey
McGRAW EDISON

CIRCLE 128 ON READER-SERVICE CARD



Special eddy current damping gives flat response

The MB Vibramite is the only damped vibration pickup available with a flat response curve over its entire operating range.

Other highly desirable features include extremely small size, light weight and omnidirectional use.

Check these specifications:

Frequency range	20-2000 cps
Sensitivity	96.3 mv/in/sec. (Calibrated ±1% at 100 cps into 2 megohm load at 80°F)
Size	1" x 1.42"
Weight	2.75 oz
Natural frequency	15 cps
Damping	Eddy current (nominal .65 of critical)
Acceleration output limit	50 g maximum (minimum limited only by recording equipment)
Max. shock without damage	1000 g

Complete technical details in Bulletin 112A. Write . . .

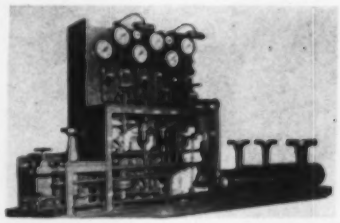
MB ELECTRONICS

A DIVISION OF TEXTRON ELECTRONICS, INC.
State Street, New Haven 11, Conn.

CIRCLE 129 ON READER-SERVICE CARD

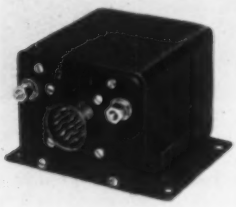
LOW-COST TEST STAND

New Test Stand tests all valves including globe, gage, plug cocks, safety and relief, plus other hydraulic-pneumatic equipment up to 2000 psig for air and 6000 psig for water. A built-in compressor provides a useful source of compressed air for general plant service.—*Farris Engineering Corp., 610 Commercial Ave., Palisades Park, N. J.*



CIRCLE 288 ON READER-SERVICE CARD

PRECISION VOLT DETECTOR

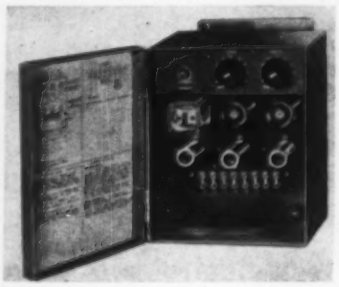


New Signal Comparator #224-023A a high-precision Voltage Detector, provides go/no-go comparison of a signal voltage with respect to a reference. Features include compact construction with all-transistor circuitry while low power drain permits ready inclusion into automated check-out and similar systems where space is at a premium. Bulletin 137-1 gives details.—*Avien, Inc., 58-15 Northern Blvd., Woodside, N. J.*

CIRCLE 289 ON READER-SERVICE CARD

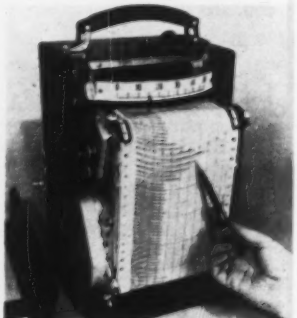
ELECTRONIC COUNTER

New fully-electronic inexpensive Predetermining Counter, Tally-Count 242, capable of batching in quantities up to 100 is for automatic control of industrial processes actuating equipment at any pre-set count from 2 to 100, at speeds faster than 1,000 operations/min. Incorporating all the advantages of electronic counting such as high speeds, no moving parts to wear, instantaneous reset to zero at the completion of each batch, its actuation is by external contacts (microswitch, magnetic switch, toggle switch, relay).—*Standard Instrument Corp., 657 Broadway, New York 12, N. Y.*



CIRCLE 290 ON READER-SERVICE CARD

TIME-SPEED RECORDER



New Time-Speed Recorder monitors automated operations, that provides split-second timing along with "time-of-day" information. This accurate timing aids in detecting equipment malfunction or other difficulties often missed by stop-watch time studies. Standard chart speeds of ¾", 1½", 3", 6" and 12" per hour and per minute are provided.—*R. B. Annis Co., 1101 N. Delaware St., Indianapolis 2, Ind.*

CIRCLE 291 ON READER-SERVICE CARD

ARE YOU PROPERLY GEARED FOR

MINIATURIZATION?

USE THE PERFECT COMBINATION
For MICRO-DRILLING

SPHINX
HIGH SPEED STEEL MICRO-DRILLS

Drills from .0016" to .0591" are stocked in increments of .0004"(.01 mm). From .0610" to .1181" in increments of .0020" (.05 mm). Left hand micro-drills for use on Swiss type automatic screw machines. Short flute center drills. Send for Bulletin "Q" listing complete line of drills or Catalog T listing collets as well as full line of instrument lathes and accessories.

Louis Levin & Son, Inc., 3610 S. Broadway, Los Angeles 7, California.

LEVIN ®
SUPER PRECISION COLLETS

Super precision collets for jewelers type lathes. Ideal for holding micro-drills or other parts where concentricity is important. Available from stock in complete range of sizes from .004" (.1 mm) to 5/16" (8.0 mm).

CIRCLE 130 ON READER-SERVICE CARD

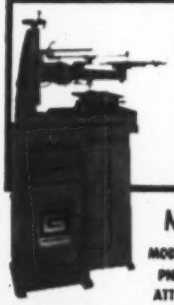
● **ELIMINATE DELAYS!**

● **KEEP YOUR OPERATING COSTS WHERE THEY SHOULD BE!**

PORTABLE
40-POUND BENCH MODEL 106

Here is a speedy, economical 2 or 3-dimensional engraver used by thousands of dollar-conscious companies. It features 5 positive, accurate pantographic ratios, ball bearing spindle with 3 speeds up to 14,000 rpm. Is supplied with one copy carrier that accepts all standard master type sizes. Will actually work up to 10" by any width. Height of pantograph and position of cutter are continuously adjustable.

You Make Your Own Engraved Nameplates!



MODEL D-2 HEAVY-DUTY 2-DIMENSIONAL
Pantograph for milling, drilling and engraving.

Vertical adjustment of copy table automatic with Pantograph. Features: unobstructed on 3 sides to take large work; micrometer adjustment for depth of cut; ball bearing construction throughout; spindle speeds up to 26,000 rpm for engraving or machining; vertical range over 10"; ratios 2 to 1 to infinity — master copy area 26" x 10"

NEW
MODEL D2-201 PNEUMATIC ATTACHMENT

for use with Model D2 Pantograph Engraver to rapidly drill holes in printed circuits by tracing templates. Drills as many as 100 holes per minute. Equipped with foot switch; spindle air cylinder; regulating valve and pressure gauge; filter and oiler. It's ready to use as soon as it's attached to an air compressor.

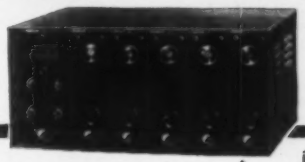
Write or call for full details and prices.

GREEN INSTRUMENT COMPANY, INC.
Dept. 86, 295 Vassar St.
Cambridge 39, Mass. Tel. Flint 4-2980

CIRCLE 131 ON READER-SERVICE CARD

TALLY-COUNT®—*an electronic*
PREDETERMINING COUNTER

Standard 2-decade model:
$245.00



TALLY-COUNT is a versatile instrument, ideal for batch counting, packaging, unit flow and machine cycling. Tally-Count provides electronic speed and accuracy, at a price usually associated with electro-mechanical counters.

Plug-in decades (up to 5) $50 each

unique chassis design for plug-in sensing devices

A wide range of photoelectric and other sensing devices extends Tally-Count versatility. These devices plug into amplifiers, which can be incorporated as integral elements of the chassis. Tally-Count supplies all power for these sensing devices. No other power supply is needed.

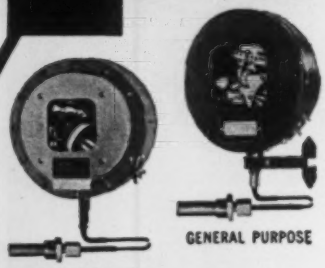
Tally-Count operates accurately at speeds up to 100 per second. Batching capacity (5-decade model) is 100,000. Instantaneously resets to zero at desired count. Double and triple pre-set models available.

For full details, write for Brochure JT-9.

standard INSTRUMENT CORPORATION
657 BROADWAY, NEW YORK 12, N.Y.
In Canada: STANDARD INSTRUMENTS (CANADA) LTD.
767 Warden Ave.

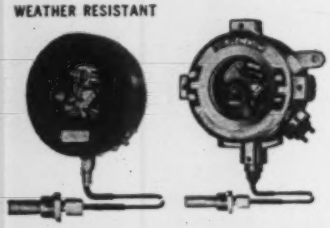
CIRCLE 132 ON READER-SERVICE CARD

4 SERIES OF MERCOID TEMPERATURE CONTROLS



GENERAL PURPOSE

WEATHER RESISTANT



Two-Stage

EXPLOSION-PROOF

Each with these features:

External Adjustment
Sealed mercury contact
Visible calibrated dial
Visible on-off circuit
Repetitive trip point

Thirteen adjustable operating ranges from —60 +30° to 370-530°F.

Available in three case styles:
General Purpose (NEMA 1)
Weather-Proof (NEMA 1A, 2, 3, 4)
Explosion-Proof (NEMA 7, 9)

Series D-35 (10A. 115V., 5A. 230V.) Double adjustments for setting both high and low (on-off) operating points.

Series D-535 (close differential type) 5A. 115V., 2½A. 230V.) Double adjustment type for setting both high and low (on-off) operating points.

Series D-235 (very close differential type) 0.3A. 115V., 0.15A, 230V. Single adjustment for setting operating point only (minimum differential is factory set).

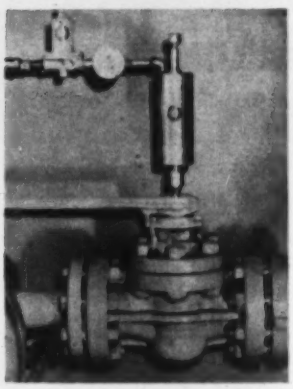
Series D-435 (Two-Stage Type) operates two SP-ST magnetic mercury switches at different temperatures to provide stage operation.

Write for
CATALOG, NO. 860
THE MERCOID CORPORATION
4201 Belmont Ave., Chicago 41, Ill.

CIRCLE 133 ON READER-SERVICE CARD

I&CS NEW INSTRUMENTS

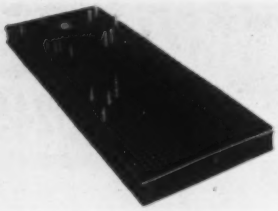
AUTOMATIC VALVE LUBRICATOR



New automatic Valve Lubricator, designed to provide lubricated plug valves with a continuous and regulated supply of lubricant can be set to furnish lubricant only when the valve requires it. Other advantages include: a built-in indicator; remote control by equipping it with a limit switch; lightweight. Lubricator consists of only three basic parts—piston, cylinder, and lubricant chamber. —*Rockwell Mfg. Co., Meter and Valve Div., 400 North Lexington Ave., Pittsburgh 8, Pa.*

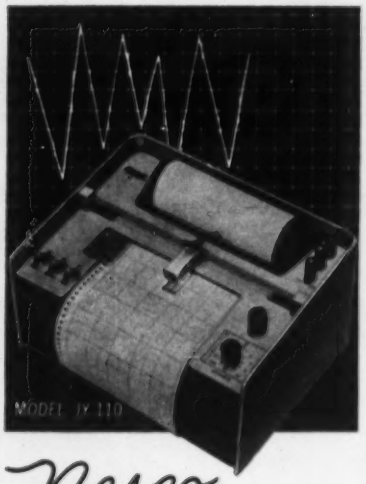
CIRCLE 292 ON READER-SERVICE CARD

CIRCUIT-SWITCHING DEVICE



New Sealectoboard is a new Circuit-switching/Component interposition Device which allows instantaneous set-up, or programming of circuitry logic between X and Y axes of terminations, without the use of patch-cords, and at the same time permits interposition of diodes, or other miniature electronic components between any X and Y termination. Consisting of two separate layers of formed, silver-plated, beryllium-copper contacts mounted on plastic boards at right angles and separated by spacers, the two planes of contacts are connected in an X and Y axis configuration to outside circuitry. Available in any size. Plug-ins are based on 0.250" x 0.250" modules.—*Sealectro Corp., 139 Hoyt St., Mamaroneck, N. Y.*

CIRCLE 293 ON READER-SERVICE CARD



Nesco

GRAPHIC RECORDER -offers exceptional sensitivity, speed, and accuracy...

as low as **$320.00**
(Model JY-100)

Here is a superior quality recording potentiometer, engineered for modern laboratories, and offering these advantages—all standard:

Fast balance time—only ½ second.
High accuracy—½% of span.
Span: 10 mv (Model JY-100); 10 mv to 100 V, with 10-step attenuator (Model JY-110)
5" chart width
Hum suppressor minimizes stray 60-cycle pickup.
Chopper stabilized—no zero-drift problems.
Floating high-impedance input — with separate chassis ground.
Many other quality features. Write for complete data.

Nesco
INSTRUMENTS, INC.
Manufacturers of Precision Recording Instruments
538 West 17th St., Costa Mesa, Calif.

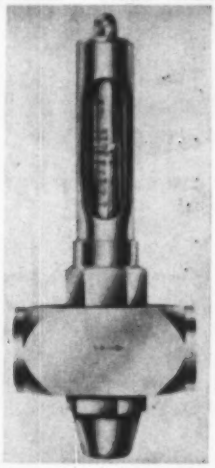
CIRCLE 134 ON READER-SERVICE CARD

SCREW THREAD COMPARATOR

New O-Vee Screw Thread Comparator brings the accuracy of the wire method of screw thread measurement right down to absolute simplicity, indicating the variation of pitch diameter on the scale equipped with tolerance pointers. Measuring elements are pairs of helical springs of the correct size wire to suit the thread being measured. Each pair of springs is housed in a container clearly marked with the pitch of the screw for which the springs are intended. Tested and approved by the National Bureau of Standards, its accuracy is well within gage tolerances. Available in 3 models, ranging from ⅛" to 1¼"; 1" to 2¼" and ¼" to 1⅝" with simplified backstop.—*Scherr-Tumico, 200 Lafayette St., New York 12, N. Y.*

CIRCLE 294 ON READER-SERVICE CARD

ARMORED PURGE METERS

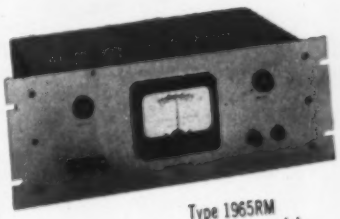


New line of Armored Purge Meters withstands pressures to 1500 psi, and temperatures to 400°F. Meters have water capacity from 1.6 to 100 gph, and air capacity from 7.5 to 420 scfh. All piping connections are ½" NPT. A magnetic indicator travels on the inside surface of a precision-bore scale tube, which is calibrated with both water and percentage scales. Catalog File No. 510.200 gives details. —*Wallace & Tiernan, Inc., 25 Main St., Belleville, N.J.*

CIRCLE 295 ON READER-SERVICE CARD

GALVANOMETERS
for Precise Null Indication

Type 1965 table model



Type 1965RM rack mounting model

ELECTRONIC

Shallcross Electronic Galvanometers are mechanically and electrically designed for rapid, maintenance-free laboratory and production testing. The extremely high sensitivity detects the balance point immediately . . . minute deflections are registered instantly. Meter becomes balanced in less than one second. Adjustments are quickly made from front of panel.

Current sensitivity is greater than 1×10^{-10} amps.

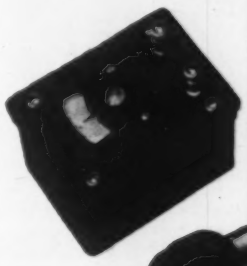
Voltage sensitivity is greater than 0.5 μv/scale division.

Electronic galvanometers are available in both table and rack-mounting models. Delivery is immediate. Ask for Bulletin L-47.

MOVING COIL

These rugged Shallcross taut-suspension galvanometers are widely used in potentiometer and bridge circuits where precise balance indication is needed at low cost.

Complete instruments or their systems are available in sensitivities of 0.5, 1, 2, or 4 μa/mm scale division. Complete specifications are in Bulletin L-47.



Type 315

Type 1951 system

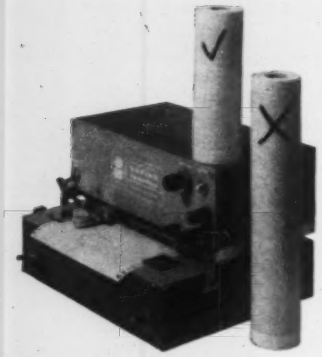
Shallcross

SHALLCROSS MANUFACTURING CO., Selma, N. C.

CIRCLE 135 ON READER-SERVICE CARD

VARIAN
Potentiometer
RECORDERS

A preferred size for many uses because . . .



8. FIVE-INCH CHARTS ARE

ECONOMICAL.

A 50% savings in paper can mean hundreds or thousands of dollars in the life of a recorder. Five-inch charts are handier too for notebooks, reports or files. And in round-the-table conferences, smaller charts can be set side by side, giving more data and less clutter.

1 & 2 channel versions use same 5-inch chart paper; 1% limit of error and 1 or 2½ second full-scale balancing time; chart speeds from ½ inch per hour to 16 in./min.; prices from $365; numerous options described in Varian literature. Write the Instrument Division.

VARIAN associates

PALO ALTO 27, CALIFORNIA

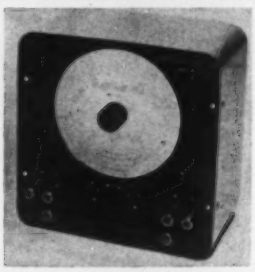
CIRCLE 136 ON READER-SERVICE CARD

VIDICON

New GEC 7697 Vidicon for industrial TV cameras has automatic sensitivity control requiring a low value of signal electrode voltage held to close limits. This compact tube provides excellent live pickup with 0.2 ft-candle illumination at the face plate. Features: patented internal construction eliminates all restrictions on operating position. Improved photoconductive surface provides excellent lag characteristics and high sensitivity at low light levels.—*General Electrodynamics Corp., Garland, Texas.*

CIRCLE 296 ON READER-SERVICE CARD

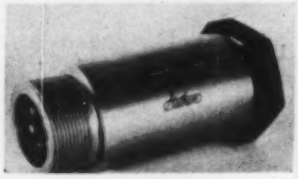
IMPEDANCE ANALYZER



New Model W-2 Impedance Analyzer computes and directly indicates phase angle as well as its sine, cosine, and tangent, power factor, Q, and D. Accuracy of at least 1% is attained over a frequency range from 60 cps to 12 kc.—*Western Electronic Products Co., 2420 North Lake Ave., Altadena, Calif.*

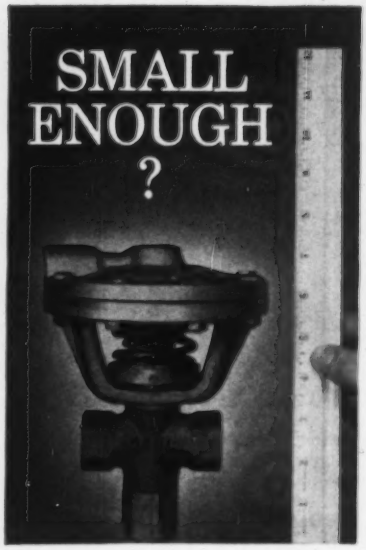
CIRCLE 297 ON READER-SERVICE CARD

PRESSURE TRANSDUCER



New Pressure Transducer, Model P713, using the Statham zero-length, unbonded, strain-gage principle, is available for applications requiring absolute, gage, and both bi-directional and uni-directional differential pressure transducers. The series is an industrial version of the types supplied in the past to the aircraft and missile industries. Pressure ranges for uni-directional differential models are from 0-5 to 0-5000 psi. The bi-directional differential model is available in ranges from ±2.5 psid to ±50 psid and is operational with line pressures up to 500 psig. With 5 v dc or ac excitation, the transducers provide a nominal 25-mv output for full-range excursion.—*Statham Instruments, Inc., 12401 West Olympic Blvd., Los Angeles 64, Calif.*

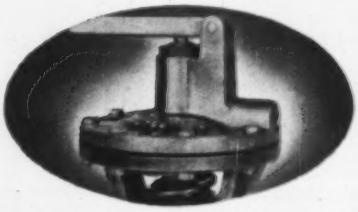
CIRCLE 298 ON READER-SERVICE CARD



DAHL 4000 Series Valves are approximately 7" in height — which offers optimum utility, size and price.

The 4000 Series features:

- Direct or Reverse Acting Operators
- Manual Reset Operators
- (Other Operators Available.)



Six body types are available in ⅛" to ½" NPT sizes:

No. 100 – 2-way with "O" ring stem seal
No. 105 – 2-way with Teflon packing
No. 110 – 3-way with atmospheric bleed
No. 115 – 3-way with Teflon packing and piped exhaust
No. 120 – 3-way with "O" ring seal and piped exhaust
No. 125 – 3-way with "O" ring seal (all ports closed in mid position)

Write for complete details today

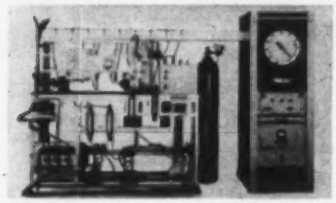
GEORGE W. DAHL COMPANY, INC.

66 TUPELO STREET
BRISTOL, RHODE ISLAND
Clifford 3-9500

VALVES AND CONTROLS FOR THE COMMUNICATIONS, PROCESS, AIRCRAFT AND MARINE INDUSTRIES

CIRCLE 137 ON READER-SERVICE CARD

WASTE WATER ANALYZER



New Analyzer for continuously determining and recording dissolved organic matter in chemical plant waste water has full-scale sensitivity of 200 ppm by weight of organic carbon which may be extended to about 1000 ppm. Concentration changes of approximately 1 ppm organic carbon can be detected. Provisions are made for automatic standardization and analysis of batch samples.—*Lockwood & McLorie, Inc., Box 113, Hatboro, Penna.*

CIRCLE 299 ON READER-SERVICE CARD

SOLID-STATE COUNTER-TIMER

New Model 361-R is a 1-Mc Counter-Timer which performs the following measurements: (1) totalizing random events over any of 8 time intervals from 10^{-4} to 10 sec; (2) frequency from 0 to 10^6 pulses/sec or 1 to 10^6 cycles/sec; (3) time interval from 10^{-6} to 10 sec; (4) period from 10^{-6} to 10^7 sec; (5) frequency ratio; (6) phase angle from 0 to 180°; (7) pulse width; (8) velocity; (9) flow rate; (10) rpm. (The last 3 with appropriate transducers.)—*Transistor Specialties, Inc., Terminal Dr., Plainview, L. I., N. Y.*

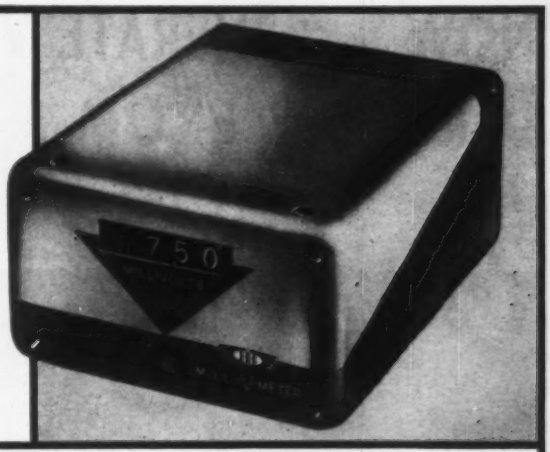
CIRCLE 300 ON READER-SERVICE CARD

MAGNETIC TAPE PLOTTER

New Magnetic Tape Dataplotter, Model 3400, including an X-Y Plotting Board, Model 205, (Variplotter) is used to convert digital data recorded on magnetic tape in IBM 704, 709, or 7090 format into inked plots on 30" x 30" or smaller graph sheets. Unlike previous models, data may be read directly from magnetic tape.—*Electronic Associates, Inc., Long Branch, N. J.*

CIRCLE 301 ON READER-SERVICE CARD

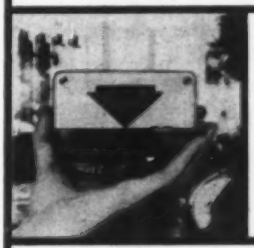
Only $285 per pound (proxl) —and They're real space savers, too.



The Series BH100

MILLI-V-METER®

The Instrument with the TAPE-SLIDEWIRE



for PETROLEUM, CHEMICAL, STEEL, ALUMINUM and other processing plants...

to accurately indicate

TEMPERATURE, FREQUENCY, FLOW, LEVEL, PRESSURE, R.P.M., WEIGHT, etc.

Every function of the producing plant may be measured *and controlled* with high accuracy. Ideally small and designed for uniform panel installation, the MILLI-V-METER is completely self-contained...including power supply, servo unit, slidewire and amplifier. Every measurement exhibited on the counter is a precisely (electronically) calibrated value.

1/10 *the size*

10 times the accuracy

of standard instruments

QUALITIES

1) Accuracy 1 part in 1000. Laboratory precision for industry or the military.
2) Compatibility with any transducer—AC or DC.
3) For strain gage, linear differential transformer, thermocouple, thermistor, resistance thermometer, pulse or variable frequency circuits or systems.
4) Operates directly from 60- or 400-cycle power as specified.

SPECIAL FEATURES

For Recording...a re-transmitting slidewire may be provided within the case.

For Controlling...switch contacts may be provided to operate control units, remote indicators, or printers.

For Computers or Telemetering...counters with decimal outputs may be added.

Produced by the makers of JETCAL® *jet engine Analyzer ...in worldwide military and airline use!*

Full information is available for the asking!

Sales-Engineering Offices:
ATLANTA, GA.; COMPTON, CAL.
DAYTON, OHIO; WICHITA, KAN.
VALLEY STREAM, L. I., N. Y.
TORONTO, ONT. (*George Kelk Ltd.*)
MITCHAM, SURREY, ENGLAND
(*Bryans Aeroequipment Ltd.*)

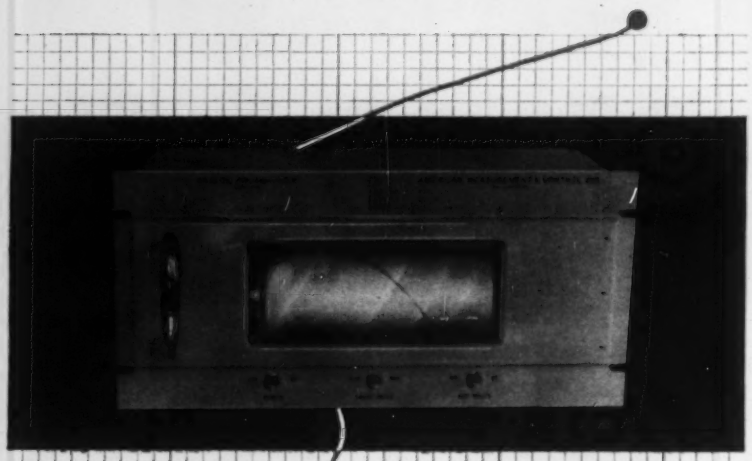
HOWELL INSTRUMENTS, INC.

FORMERLY BAN INSTRUMENT CO., INC.

3479 WEST VICKERY BLVD. • FORT WORTH 7, TEXAS

CIRCLE 138 ON READER-SERVICE CARD

NOW. . . GENERATE VOLTAGE DIRECTLY FROM A GRAPH



The Model 750 Analog Programmer — new from AM&C — provides the simplest and most reliable method yet devised for generating arbitrary functions for analog simulators, computers, or process controllers. It gives a continuous voltage output directly proportional to any single-valued function (Y) drawn in conductive ink directly on graph paper as a function of time (X). Accuracy is ±0.5% and full-scale response is less than 10 microseconds.

The Analog Programmer consists basically of a chart-supporting drum and potentiometer roller. A portion of the externally applied potentiometer reference voltage is picked off where the drawn curve intercepts the potentiometer. Thus, at any specific instant of time (X), the output voltage is proportional to the ordinate value (Y) of the drawn curve. Synchronously-motor driven at preselected speeds, an infinite variety of program time conditions are available. Drum can also be servo-motor driven, thus making (X) a function of an independent variable.

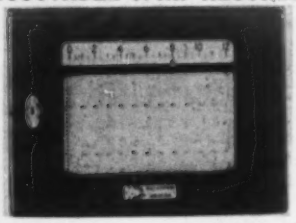
Programmer is unequalled in flexibility and convenience for missile flight simulation, structural testing, linear programming of non-linear function, and automatic control of industrial operations and processes.
Write for literature.

AMC AND

AMERICAN MEASUREMENT & CONTROL, INC.
WALTHAM 54, MASSACHUSETTS
Subsidiary of CompuDyne Corporation

CIRCLE 139 ON READER-SERVICE CARD

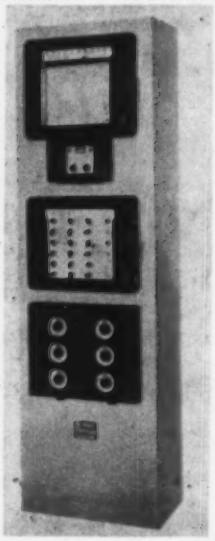
ADJUSTABLE-SPAN RECORDER



New Model 6701, a null-balancing type adjustable-span/adjustable-zero Recorder, employs a line-driven synchronous converter and amplifier to control a two-phase motor which rebalances the measuring circuit. Millivolt input, either direct or from a transducer, is converted into a visual indication and a permanent chart record. Recorder covers spans between 1 and 250 mv, placing the lowest nominal span at 5 mv (1-10) and the highest nominal span at 125 mv (25-250). Zero adjustment is marked in arbitrary units from 0-1000, and any span selected may be shifted (without change) over a maximum of ±50 mv.—*Weston Instruments Div., Daystrom, Inc., 614 Frelinghuysen Ave., Newark 12, N. J.*

CIRCLE 302 ON READER-SERVICE CARD

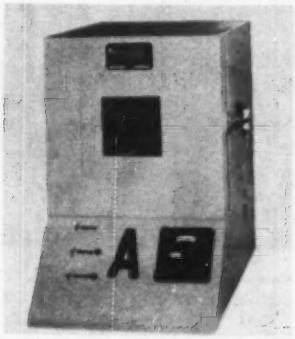
UNIVERSAL PROGRAMMER



New Program Unit originally designed for the metallurgical research field in connection with the processing of many of our new and sophisticated metals features extreme flexibility. Typical programs which might include three time temperature rises, and three soak periods, as well as two temperature rises, one fall, and a soak period along with all the combinations which can be achieved by the use of index switches, timers, and input controllers are all finger-tip controlled. Bulletin F-9946 describes unit in detail.—*Wheelco Instruments Div., Barber-Colman Co., Rockford, Ill.*

CIRCLE 303 ON READER-SERVICE CARD

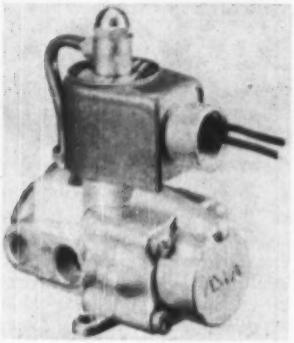
LO-HI TEMP TEST CHAMBER



New Econ-O-Line low-high Temperature Test Chamber with internal working dimensions of 14" x 14" x 14" utilizes liquid carbon dioxide and spans a temperature range —100°F to 350°F. The unit uses a United Electric Indicating Controller and guarantees accuracy to within a range of ±2°F.—*Associated Testing Labs., Inc., Caldwell, N. J.*

CIRCLE 304 ON READER-SERVICE CARD

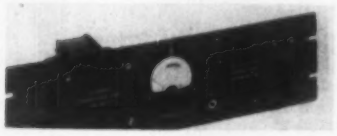
4-WAY SOLENOID VALVE



New single-solenoid, two-position, 4-way Solenoid Valve has ¼" orifices, a forged brass body (available in ¼" or ⅜" pipe connections) and poppet type seats and discs. Bulletin 8344, Form No. V5109 gives details.—*Automatic Switch Co., Florham Park, N. J.*

CIRCLE 305 ON READER-SERVICE CARD

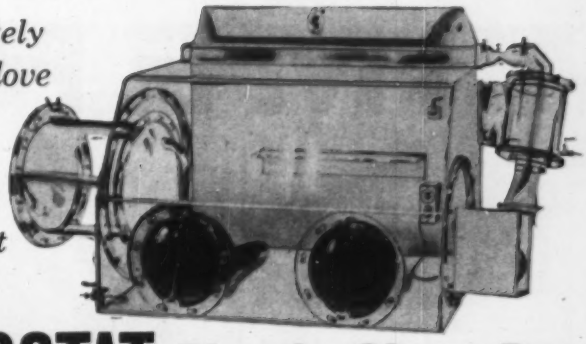
TRANSFORMER PANEL



New Accessory Tranformer Panel, Model 250-X1, is used in conjunction with the 250 AR Laboratory/Industrial Power Amplifier and provides a convenient source of up to 130 vac over a frequency range from 30 cps to 10 kc. Voltmeter indicates output voltage between 80 and 150 v ±1%.—*H. H. Scott, Inc., Instrument Div., 111 Powdermill Rd., Maynard, Mass.*

CIRCLE 306 ON READER-SERVICE CARD

Moderately priced glove boxes with positive gas-tight seals!



MANOSTAT Plastic Glove Box

Manostat Plastic Glove Boxes with true one-piece construction, achieved with a chemical weld. Despite their moderate price, these boxes are designed and constructed with such de-luxe features as positive "0" ring seals throughout, for leak-proof performance... and a full 18" diameter side entry, for maximum convenience. The ¼-inch thick Rohm & Haas Plexiglas 11-UVA is unaffected by most inorganic solutions, mineral and animal oils, low concentrations of alcohol, paraffinic and olefinic hydrocarbons, amines, alkyl monohalides, and esters containing more than ten carbon atoms.

PRICE LIST:

GB1100 – SIMPLE GLOVE BOX, ready for use, with side cover plates and all other accessories, as shown. (Does not include air lock or circulating system.).....**950.00**

GB1200 – AIR LOCK GLOVE BOX, ready for use, with air lock and all accessories, as shown. (Does not include circulating system.).....**1,150.00**

GB1300 – CIRCULATING GLOVE BOX, ready for use, with circulating system and all accessories, as shown. (Does not include air lock.).....**1,250.00**

GB1400 – COMPLETE GLOVE BOX, ready for use, with air lock, circulating system and all accessories, as shown.....**1,495.00**

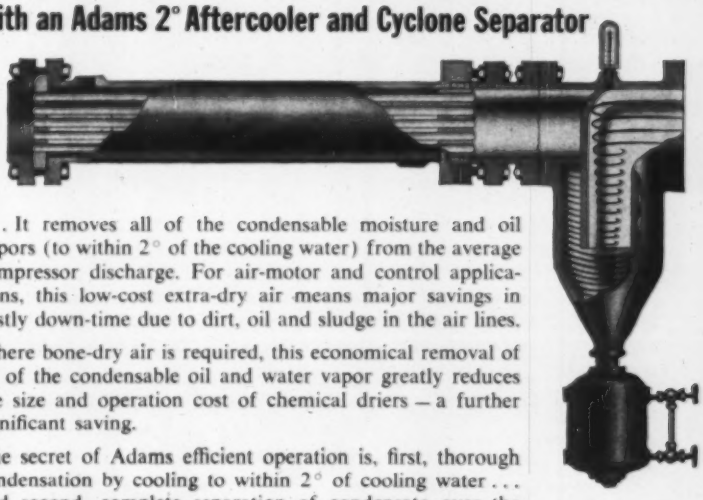
See Your Laboratory Supply Dealer • Write For Bulletin PG

MANOSTAT Corporation 26 N. MOORE STREET • NEW YORK 13, N. Y.

CIRCLE 140 ON READER-SERVICE CARD

BE SURE OF CLEAN, DRY, OIL FREE INSTRUMENT AIR

with an Adams 2° Aftercooler and Cyclone Separator



... It removes all of the condensable moisture and oil vapors (to within 2° of the cooling water) from the average compressor discharge. For air-motor and control applications, this low-cost extra-dry air means major savings in costly down-time due to dirt, oil and sludge in the air lines.

Where bone-dry air is required, this economical removal of all of the condensable oil and water vapor greatly reduces the size and operation cost of chemical driers – a further significant saving.

The secret of Adams efficient operation is, first, thorough condensation by cooling to within 2° of cooling water... and second, complete separation of condensate over the entire operating range with the exclusive Adams cyclone separator.

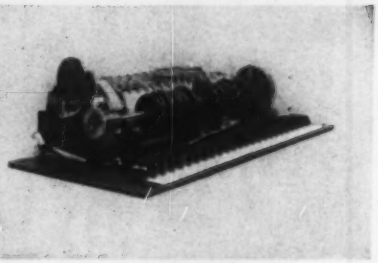
Why not be sure of clean, dry, oil free — trouble free instrument air in your installation? Write today for Bulletin 714 and recommendations on your particular application.

R. P. ADAMS CO., INC. • 265 East Park Drive, Buffalo 17, N. Y.

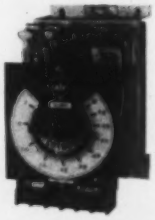
CIRCLE 141 ON READER-SERVICE CARD

TIMERS

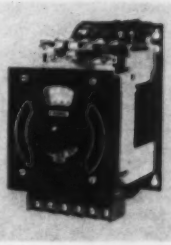
Multi-Circuit Cam Timers control sequence and duration of one or a series of operations. Time cycles from ⅔ of a second to 7 days. Controls 1 to 100 circuits in any length of "made" or "broken" periods desired. Choose either Repeat or Stop Cycle operation. **Series 2400**



Electronic Timers provide high accuracy and constant, exact repeatability for intervals from .02 to 120 seconds. Unaffected by vibration, tube aging, line voltage fluctuations. Printed circuit design, few mechanical parts mean long life at fast, repetitive cycling. **Series 5200**



Heavy Duty Reset Timers automatically and instantly reset on power interruption. SPDT heavy duty load contacts carry 25 amps. Available for vernier adjustment or cycle progress indication. **Series 2800**



Revolution Counters count shaft revolutions at speeds up to 1000 rpm, with only 1¼ oz. in. torque on input shaft. For measuring, product counting or cut-off, fluid metering, drill depth control, indexing, etc. Ideal where process variations occur and pulse count is not adequate. **Series 307**

IF IT'S A TIMING PROBLEM, SEE ATC. Wide product selection includes cam timers, automatic reset timers, revolution counters, electronic timers, impulse counters, transistor timers, many others.
Special timers and counters designed to your requirements.

Send for your free Condensed Catalog "Automation Components and Control Systems"—today!

atc

AUTOMATIC TIMING & CONTROLS, INC.
KING OF PRUSSIA, PENNSYLVANIA
A Subsidiary of American Manufacturing Company, Inc.

ATC, Div. of Interprovincial Safety Industries, Ltd., 5485 Notre Dame St., West, Montreal 30, Quebec

CIRCLE 142 ON READER-SERVICE CARD

PENCIL-PROBE T/C

New Model G Pencil-Probe Thermocouple features a response time of less than 10μsec, a continuous service temperature of over 2000°F, a sensing tip with unlimited life, and an operating pressure range of 3,000 psig. Design uses thin ribbon thermocouple wires and mica insulation of 0.0002" thickness. Stainless-steel construction is used on the body of the instrument. It is available in all standard thermocouple elements.—*Nanmac Corp., Dept.* 128, *Box* 8, *Indian Head, Md.*

CIRCLE 307 ON READER-SERVICE CARD

SPECTROPHOTOMETER

New low-cost modular Spectronic "505" Reording Spectrophotometer includes such outstanding features as automatic wavelength speed control, external dual lamphouse, air-cooled hydrogen lamp, built-in wavelength calibration, large sample compartment, and uniquely designed monochromator. The compact instrument has been constructed on a "building block" design which simplifies the removal and replacement of major components and accessories.—*Bausch & Lomb Optical Co., Rochester* 2, *N. Y.*

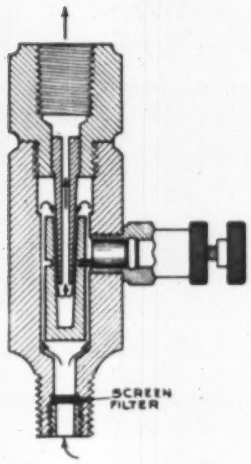
CIRCLE 308 ON READER-SERVICE CARD

THERMOCOUPLE ASSEMBLIES

New complete Trinox Thermocouple Assemblies utilize a miniaturized, self-sheathed unit with closed, closed and grounded, or exposed thermocouple junctions. The assemblies are completely factory-assembled and ready to use. Four cold junctions are offered: (1) direct-connected, (2) universal head, (3) two-pin plug, and (4) miniature thermocouple head. A standard 3" extension is offered on all assemblies. Diameters range from 0.040" to ⅛".—*Trinity Equipment Corp., Cortland, N. Y.*

CIRCLE 309 ON READER-SERVICE CARD

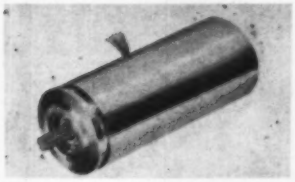
GAGE SAVER



New Throttler working on the variable-restricted-orifice principle protects gages from pulsation, regardless of the viscosity or surface tension of the pressure medium and of the amplitude or frequency of the pulsation. Suitable for any pressure medium which will not deteriorate brass and for pressures that exceed 600 psig.—*Marshalltown Mfg. Co., Marshalltown, Iowa.*

CIRCLE 310 ON READER-SERVICE CARD

SERVO MOTOR



New Size 8 viscous-damped Servo Motor Type 5702-03, is smaller (only 1.75" long), lighter (weighs only 2oz), consumes less power, and presents no null- or phasing-problems in the feedback loop in contrast to motor tachs commonly used in such applications. Damping and gain can be independently adjusted. No-load speed is adjustable between 6500 and 3250 rpm to exact speed required.—*John Oster Mfg. Co., Avionic Div., Racine, Wis.*

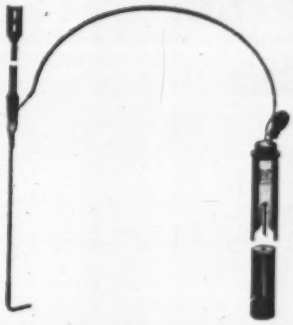
CIRCLE 311 ON READER-SERVICE CARD

S.-S. REGULATOR

New all-stainless-steel Pressure Regulator, Series 640 for use with corrosive fluids and in corrosive atmospheres features seat and diaphragm of Teflon and seating disc and O-ring seals of Kel-F. Maximum inlet pressure is 2000 psig. Monel models, made as alternate, have wetted parts of monel and non-wetted parts of 18-8 stainless.—*Hoke Inc., 31 Piermont Rd., Cresskill, N. J.*

CIRCLE 312 ON READER-SERVICE CARD

NEW! Meter Recorder Marking System with a Slip-In Cartridge!



Esterbrook's *customized* marking systems guarantee you complete satisfaction . . . for *any* type recorder . . . Circular . . . Strip . . . Miniature *or* Plotter!

Customized for your meter recorder by Esterbrook

Give your customers the benefit of *ink cartridge convenience*, and a century of experience in the recording product you build. . . . Now—Esterbrook's Technical Products and Instrument Division will custom-design and build a new marking system for *your* product.

The result: no more breaking down . . . no more hand fixing! With Esterbrook's new *customized* meter recorder you'll conserve operating time . . . *and* you'll receive the free design time and engineering assistance of experts!

For further information write to:
Technical Products & Instrument Division
The Esterbrook Pen Co. • Camden 1, N. J.

TECHNICAL PRODUCTS AND INSTRUMENT DIVISION

The Esterbrook Pen Company
CAMDEN 1, NEW JERSEY

CIRCLE 143 ON READER-SERVICE CARD

NIXIE TUBES — LOWEST COST — SMALLEST SIZE — LIGHTEST WEIGHT
NIXIE TUBES — NO DARKENING DISPLAY
NIXIE TUBES — MOST EASILY READ — UNDER ALL CONDITIONS
NIXIE TUBES — NO SHIFTING FOCUS OR MISALIGNMENT
NIXIE TUBES — ALL ELECTRONIC
NIXIE TUBES — NO COSTLY REPLACEMENT OR SERVICING
NIXIE TUBES — LOWEST POWER REQUIREMENTS
NIXIE TUBES — NO BULB OR FILAMENT FAILURE
NIXIE TUBES — MEETS MAXIMUM TEMPERATURE SHOCK AND VIBRATION SPECIFICATIONS
NIXIE TUBES — NO SEGMENTED FAILURE
NIXIE TUBES — LONGEST LIFE — 100,000 HOURS
NIXIE TUBES — NO MATRIX DRIVER REQUIRED

NIXIE®
INDICATOR TUBES

Write today for your READOUT FACT FINDER (Shows actual comparison of indicator devices)

Burroughs Corporation
ELECTRONIC TUBE DIVISION
Plainfield, New Jersey

See us at the ISA SHOW—Burroughs Booth #1402

CIRCLE 144 ON READER-SERVICE CARD

GOW-MAC GAS ANALYSIS INSTRUMENTS

By the Thermal Conductivity Method —

- HOT WIRE FILAMENTS IN MATCHED PAIRS (Available from stock)
- ON-STREAM DETECTOR CELLS
- CHROMATOGRAPHY DETECTOR CELLS For ¼" Columns and Capillary Columns*
- TEMPERATURE REGULATED CELLS TO 300° C+
- PORTABLE ANALYZERS (Gas Masters)
- PANEL INSTRUMENTS — Indicate — Record — Control
- GAS BLENDER (Automatically mixes forming gas and other binaries)
- EXPLOSION-PROOF UNITS

By the Gas Density Method —

- DETECTOR CELLS*
  - — No Calibration Required
  - — Linear Across Broad Ranges
  - — Less than 1% Error
  - — Nitrogen Eluting Gas
  - — Non-destructive to Sample

*Indicates new product

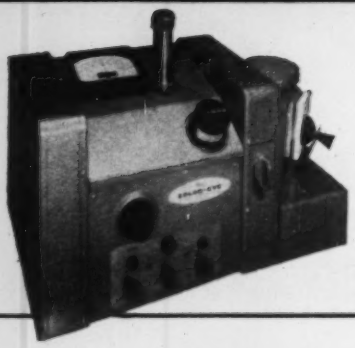
ATTEND THE I.S.A. MAINTENANCE CLINIC, "GAS ANALYZERS & PROBES" HOTEL NEW YORKER MONDAY SEPT. 26—2 SESSIONS

GOW-MAC INSTRUMENT COMPANY
100 KINGS ROAD, MADISON, NEW JERSEY, U.S.A.
Telephone FRontier 7-3450

GAS ANALYSIS BY THERMAL CONDUCTIVITY SINCE 1935

CIRCLE 145 ON READER-SERVICE CARD

Color Control WITH COLOR-EYE®



For laboratory use . . .
COLOR-EYE provides a means for developing new color formulations, color specifications and non-drifting color standards. Color-Eye can also be used for analysis of basic colorants.

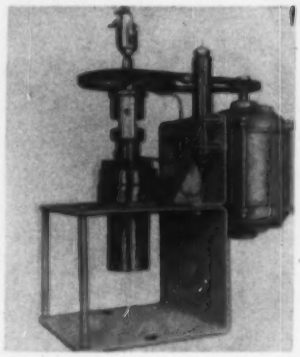
This unique combination of a colorimeter and abridged spectrophotometer measures color differences directly or against a permanent reference standard. For use in production or laboratory, Color-Eye is completely portable, rugged and stable.

Write for complete brochure
or visit Booth 1603, ISA Show

INSTRUMENT DEVELOPMENT LABORATORIES, INC.
Specialists in Photometric Analysis
67 MECHANIC STREET, ATTLEBORO, MASS., U. S. A.
Subsidiary of ROYAL McBEE CORPORATION

CIRCLE 146 ON READER-SERVICE CARD

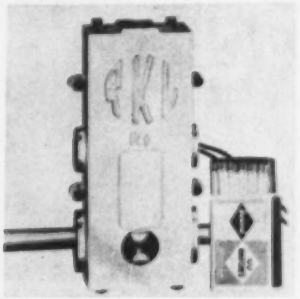
AUTOCLAVE



New Autoclave, designed for bench-scale research, features a 300-ml, 5,000 psig stirred reactor with water-cooled shaft and a special intensifying lubrication cylinder which can be used with either oil or water. The reactor can be furnished with any of the following types of stirrers: marine propeller, turbine, paddle, or gas dispersing (Gasperator).—*Pressure Products Industries, Inc., Hatboro, Penna.*

CIRCLE 313 ON READER-SERVICE CARD

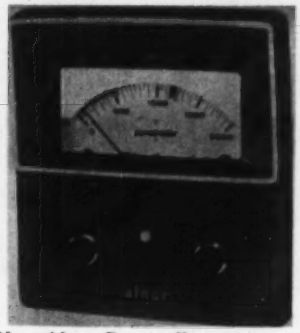
PINCH-TYPE VALVE



New solenoid-operated Pinch-Type Valve, Series Rs, that can be used for metering, sampling, or "on-off" control in applications involving corrosive fluids, slurries, dry powder, or sanitary products, provides absolutely gas-tight shut off under vacuum or pressure conditions. Made in sizes ⅛" to 1", the simple design permits straight-through flow in either direction. Normally-closed, the valve can be operated manually or from programmers, alarms, timers, or automatic sensing instruments. Standard valve bodies are of pure gum rubber with a maximum pressure rating of up to psig for the smallest size. The standard maximum temperature rating is 180°F. Synthetic-rubber valve bodies of Buna, Butyl, Neoprene, Hypalon, or Viton can be supplied for higher temperatures or other special requirements on lower-presure applications.—*RKL Controls, Inc., Hainesport Industrial Park, Hainesport, N. J.*

CIRCLE 314 ON READER-SERVICE CARD

TEMPERATURE CONTROLLER



New Alnor Pyrotroller, an accurate electronic on-off controller and pyrometric temperature temperature indicator, features small size (6⅜"x7") which makes it a highly desirable panel board instrument. Available in 11 ranges from 0-400°F to 0-3000°F, as well as an environmental test chamber range of −100 to +300°F—*Alnor Instrument Co., Div. of Illinois Testing Labs., Inc.*, 418 *N. LaSalle St., Chicago* 10, *Ill.*

CIRCLE 315 ON READER-SERVICE CARD

THERMOCOUPLE INSULATORS

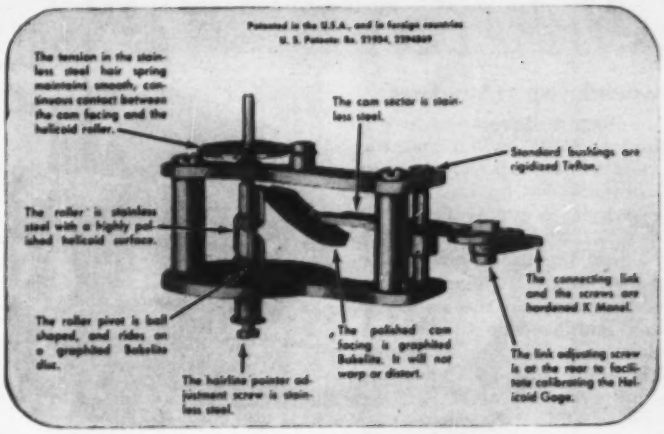
New line of Thermocouple Wire Insulators made of cordierite, steatite or mullite, the high temperature composition capable of withstanding up to 3200°F, posses good insulation properties, high thermal shock resistance, and good mechanical strength. They retain size and shape satisfactorily as insulators at temperatures up to 2800°F.—*Du-Co Ceramics Co., Saxonburg, Penna.*

CIRCLE 316 ON READER-SERVICE CARD

RACK-MOUNTED SCOPE

New Model 401BR, the rack-mounted version of the General Purpose Oscilloscope, features bandwidth of 500 kc at 3 db down ±1 db. Electronically identical to the 401B it is designed for 7"-high panels. It utilizes the new K1931 CR tube specifically developed for the new instrument with an accelerating potential of 5,000 v for exceptionally bright displays.—*Allen B. Du Mont Labs., Inc., Clifton, N. J.*

CIRCLE 317 ON READER-SERVICE CARD


The tension in the stainless steel hair spring maintains smooth, continuous contact between the cam facing and the helicoid roller.
The cam sector is stainless steel.
Standard bushings are rigidized Teflon.
The roller is stainless steel with a highly polished helicoid surface.
The connecting link and the screws are hardened K Monel.
The roller pivot is ball shaped, and rides on a graphited Bakelite disc.
The polished cam facing is graphited Bakelite. It will not warp or distort.
The link adjusting screw is at the rear to facilitate calibrating the Helicoid Gage.
The hairline pointer adjustment screw is stainless steel.

Exclusive Helicoid movement provides...
Sustained Accuracy... on the toughest jobs

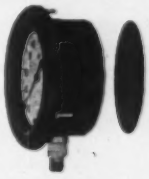
• Helicoid Gages have no gears, no teeth, reducing wear to an absolute minimum. No danger of fouling, either—rolling action of cam facing keeps contact surface clean. Helicoid Gages have been tested through 75,000,000 cycles, with virtually no wear or loss of accuracy, while conventional geared gages became useless after 500,000 cycles.

Helicoid Gages give *sustained* accuracy even when subjected to violent pressure pulsations or mechanical vibrations. Pointer can be set externally, without removing glass, and cannot be jarred out of position. Dial faces are easy to read, won't corrode or chip. A full range of Helicoid Gages is available for any application. Next time, specify Helicoid—the gage that *stays* accurate.

Bourdon Tubes won't Stretch, Leak, or Crack

Helicoid Bourdon tubes are made from seamless tubing, and are designed for maximum torque and minimum stress. At the factory, each tube is individually tested, overpressured, and stress relieved. Four materials—alloy steel, K Monel, stainless steel, and phosphor bronze—are available to meet applications ranging from tap water to almost any acid.

NEW! Solid-Front Safety Case Gives Added Protection



The new Helicoid solid-front case diverts the force of a burst in a backward direction, away from the operator. The force escapes by deforming, though not detaching, the back cover plate. Helicoid Gages are also available in phenol, acaloy flanged, acaloy flangeless, polished flangeless, round flush, polished flush ring, and square flush cases.

WRITE for details Ask for Catalog DH-65

HELICOID GAGES

ACCO

Helicoid Gage Division • American Chain & Cable Company, Inc.

929-B Connecticut Ave., Bridgeport 2, Conn.

CIRCLE 147 ON READER-SERVICE CARD

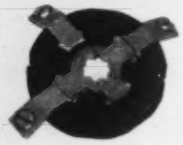
DESIGN NOTES on

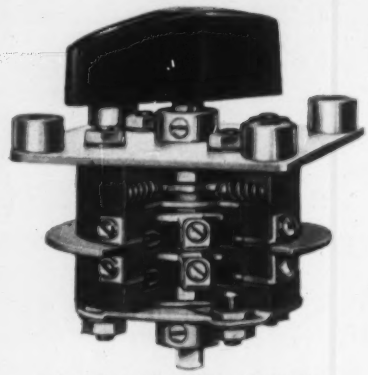
Control by Rotary Switches

No. 2 of a series

Rotary-switch Contact Structures

An important difference between the rotating-blade switch and the cam-operated switch is the way contacts are made and broken. In the rotary switch, a *wiping contact* is provided. The movable contact wipes across the full width of the stationary contact(s), clearing away dirt or corrosion as the switch is operated and keeping the contact area clean so as to minimize contact resistance and consequent heating. In some types of light-duty switches, the wiping action occurs at one side of each contact. For switches that must handle moderate or heavy currents (5 amperes to 200 amperes), the wiping action usually occurs on both surfaces of one contact (usually the stationary contact) and on the inner faces of the double-blade contact that mates with it.





Cutaway view of Type JR Switch showing positive detent mechanism.

Rotary-switch Drive Mechanisms

Two general types of drive mechanism are used with rotary switches. They are the direct drive with detent and the snap-acting type. The direct drive is generally used with light-duty switches or with switches having more than eight stationary contact positions. The detent action holds the movable contact in alignment with a stationary contact by spring loading. This is often accomplished by having the stationary contact slightly below the surface of the insulating deck and depending on the resilience of the movable contact to hold the contacts in line. While this construction is often adequate for light-duty switches, a more positive detent action is required where maximum life, reliability, and stability are necessary. Such action is provided by a separate detent mechanism in which the detent springs are not part of the electric circuit and the position of the contact-carrying rotor is established by a star wheel that engages spring-loaded balls or rollers.

With the direct drive, the speed of contact opening or closing depends on the way the operator turns the switch handle. In direct-current circuits, it is desirable to make and break contact quickly. One way to accomplish this is by using a snap-acting drive mechanism. Turning the switch handle winds a spring and, when enough energy has been stored up, the spring snaps the movable contact quickly into the next position. Because of the mechanics involved, this action is generally provided only for four-position switches although it can, under some circumstances, be furnished with eight-position switches.

Rotary-switch Circuit Possibilities

One of the most important advantages of the rotary switch is its adaptability to control of complex circuits. This aspect of design will be discussed in the next advertisement in this series.

ESCO Bulletin No. 8A, containing useful information on the construction and application of rotary switches, as well as examples of ESCO switches that utilize the design principles discussed in these advertisements, will be sent you on request.

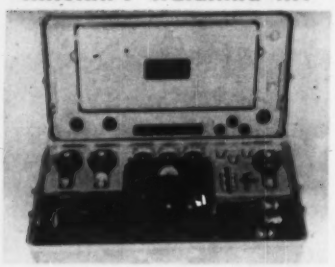
ESCO of WEYMOUTH

ELECTRO SWITCH CORP.

Weymouth (Boston 88), Massachusetts

CIRCLE 148 ON READER-SERVICE CARD

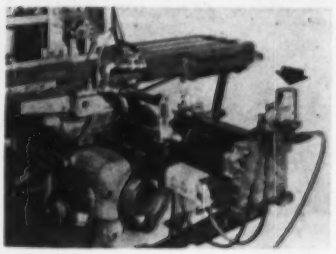
AIRCRAFT WEIGHING KIT



New portable electronic Aircraft Weighing Kit, Type C-1, capable of weighing any medium-heavy aircraft (and for determining cg location) up to a gross weight of 150,000 lb. from the forces exerted at three measuring points, features interchangeable load cells for field replacement, accuracy to $\pm\frac{1}{10}\%$ of reading, a-c or d-c operation, and a transistorized indicator with digital weight display. —*Baldwin-Lima-Hamilton Corp., Electronics & Instrumentation Div., 42 Fourth Ave., Waltham 54, Mass.*

CIRCLE 318 ON READER-SERVICE CARD

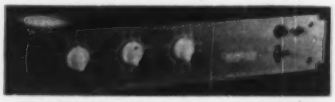
CIRCUIT HOLDER VALVE



New Crescent four-way Solenoid Valve with a built-in circuit holder simplifies wiring by eliminating the need for relays and relay circuits. It can be used to control cylinder action on a multitude of tooling set-ups where reciprocating motions are involved.—*Barksdale Valves, 5125 Alcoa Ave., Los Angeles 58, Calif.*

CIRCLE 319 ON READER-SERVICE CARD

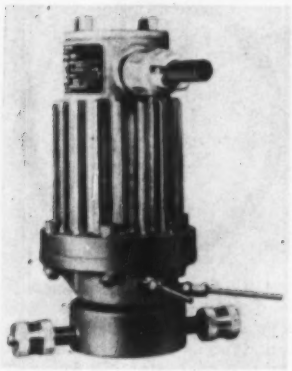
DIGITAL COUNTERS



New Chrono-log Model 8000 Digital Counters providing up to three electrical decimal outputs representing the total count are designed for moderate speed applications such as counting units passing a point in a conveyor belt system. Digital outputs are suitable for operating either serial or parallel devices such as tape punches, printers, displays, and magnetic tape recorders, as well as providing inputs to computers and data loggers.—*Chrono-Log Corp., Box 4587, Phila. 31, Pa.*

CIRCLE 320 ON READER-SERVICE CARD

GAS DENSITY ANALYZER



New Whirlweigh Densitometer which provides an output signal continuously and instantaneously proportional to gas density can be mounted also directly on a Rotron Vortex velocity-type flowmeter to convert volumetric to true-mass-flow measurement. Output signal is accurate without use of any factors or corrections for pressure, temperature, compressibility or composition and, therefore, gives a continuous measure of density of gas in pipe or vessel at line conditions.—*Rotron Controls Corp., Woodstock, N. Y.*

CIRCLE 321 ON READER-SERVICE CARD

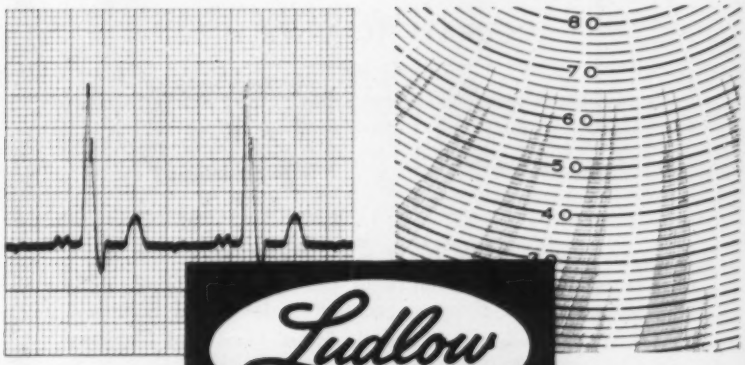
EXPANDED-SCALE RECORDERS

New Voltec, a small, compact, lightweight Miniature Recorder, which monitors voltage or frequency with an accuracy of 0.5%, consists of two sections, a miniature inkless chart recorder, and an expansion network. The recorder consists of a d'Arsonval meter with a free moving pointer. A motor driven striker cam presses the pointer against sensitized paper once each 2 sec, producing a record. Transducers for expanded scale recording of a a-c volts, d-c volts, frequency, and temperature are provided.—*Voltron Products, Inc., 1020 So. Arroyo Parkway, Pasadena, Calif.*

CIRCLE 322 ON READER-SERVICE CARD

for HEAT-Sensitive systems

for PRESSURE-Sensitive systems



Ludlow

CUSTOM
CHART PAPERS

You get the full potential from your recording systems when you use custom-made chart papers by Ludlow. Precision engineering assures constant fidelity. Write for free samples and literature or tell us your requirements. Ludlow Papers, Ware, Massachusetts, Dept. 162.

CIRCLE 149 ON READER-SERVICE CARD

MARSHALLTOWN

DIAPHRAGM GAUGES

for accurate pressure measurement in ounces or inches of water

Standard dials reading in inches of water, ounces, centimeters or millimeters up to 10 P.S.I. All Marshalltown diaphragm gauges are extremely sensitive and accurately measures very low pressures.

Let Marshalltown answer your gauge problems . . . write for information and prices.

MARSHALLTOWN MFG. CO.
MARSHALLTOWN, IOWA

CIRCLE 150 ON READER-SERVICE CARD

SPOT CRITICAL TEMPERATURES ACCURATELY with

NEW PYRO MICRO-OPTICAL PYROMETER

All-purpose PYRO Micro-Optical precisely measures targets as small as .001" in diameter or objects at remote distances to 2°C reproducibility! Temperature scales 700° - 3200°C (1300° - 5800°F).

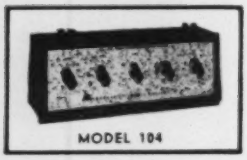
Send for FREE catalog No. 95.

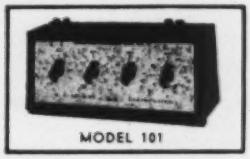
PYROMETER INSTRUMENT CO., INC.
BERGENFIELD 4, NEW JERSEY

CIRCLE 151 ON READER-SERVICE CARD

PRECISE A.C. VOLTAGE DIVISION

ACCURATE TO 10 P.P.M.


MODEL 104


MODEL 101

Precision Decade Ratio Transformers that feature high input impedance, low output impedance and negligible phase shift. Fine Instrument Switches incorporated for long term accuracy. Models shown packaged in Smartly Styled Hardwood Cabinets and priced from $210 to $305. Other models available.

- **RESOLUTION: 0.001 to Infinite**
- **INPUT VOLTAGE: 0.35f (500 Volts Maximum)**
- **ACCURACY: 0.001%**
- **OUTPUT IMPEDANCE: 1.5 Ohms Maximum**
- **FREQUENCY: 50 to 10,000 CPS**

G. L. COLLINS GLC CORPORATION

2820 EAST HULLETT STREET LONG BEACH 5 CALIFORNIA

CIRCLE 152 ON READER-SERVICE CARD

MICO *Precision Apparatus*

HEAVY DUTY 2 & 3 DIMENSIONAL ENGRAVER

FOR
Engraving Nameplates
Fine Routing Work
Profiling Small Objects
Making Small Dies and Molds

UHF COAXIAL WAVEMETERS

2-75 Centimeter Range

Send for Illustrated Catalogs

MICO INSTRUMENT CO.

86 Trowbridge St., Cambridge 38, Mass.

CIRCLE 153 ON READER-SERVICE CARD

"CLASSIFIED" for your CONVENIENCE

Product headings and advertisements in the

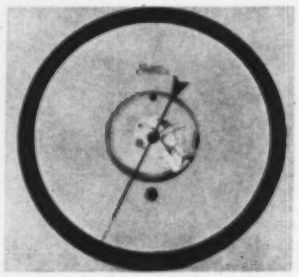
I&CS BUYERS' GUIDE

—separated into nine categories

1. industrial
2. data & recording
3. electronic
4. analytical/lab
5. servos/systems
6. testing
7. general
8. components
9. materials

—help you find product/supplier facts—faster.

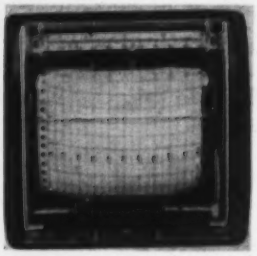
PRECISION TEST GAGE



New 8" Standards Precision Test Gage features True Zero Adjust (patent pending) which eliminates gage distortion or loss of calibration due to improper starting angle. This permits testing facilities to use the gage as a primary standard instead of the average dead weight tester. Accuracy is ± the minor subdivisions over 2. As an example: the 15 psi gage has a graduation interval of 0.025, which divided by 2 equals ±0.0125-psig accuracy. Available in ranges from 0-15 to 0-10,000 psig.—*Seegers Instrument Co., 515 West Main St., Barrington, Ill.*

CIRCLE 323 ON READER-SERVICE CARD

CASCADE CONTROL STATION



New Remote Control Station contains all the panel-mounted components needed for pneumatic cascade control of a process by using two Model 58 Consotrol controllers. The cascade station receives measurements from two different points in the process, recording them on the same chart. Output of the primary controller pneumatically adjusts the set point of the secondary controller whose output, in turn, operates the valve. Only 6" x 6" in size. —*Foxboro Co., Foxboro, Mass.*

CIRCLE 324 ON READER-SERVICE CARD

INSTRUMENT TUBING HARNESS

New Poly-Cor, a new type of Instrument Tubing Harness, features special-formulation all-black poly-

ethylene core tubes that permit operation at higher temperatures than have been possible previously with all-plastic instrument harness of this type. Core tubes are tightly wrapped with Mylar tape and then covered by an extruded vinyl sheath. Number coding of tubes and telephone test wire leads are included in the standard tubing bundle. Available in combinations of 2, 3, 4, 5, 7, 8, 10, 12, 14, 19 and 37 core tubes. Normal sizes for core tubes are ¼" OD x 0.04" wall, and ⅜" OD x 0.62" wall.—*Dekoron Products Div., Samuel Moore & Co., Mantua, Ohio.*

CIRCLE 325 ON READER-SERVICE CARD

CONTROL SYSTEM TEACHING

New Controlab is a self-contained system which includes all necessary electronic, mechanical, and electromechanical components, and equipment for teaching of feedback-control-system design and testing both in college classes and in-plant training. A unique feature is its patch panel display board on which all system components are diagrammed and color coded. Leaflet gives details.—*Shaw Controls, Inc.*, 101 *Third Ave., Garden City Park, N. Y.*

CIRCLE 326 ON READER-SERVICE CARD

DIGITAL TAPE SYSTEMS

New high-speed digital Tape System is capable of transfer rates of 300,000 characters/sec and has total storage capacity of more than 300,000,000 bits on one 6-inch file reel of 1-inch wide magnetic tape. Unusually low average access times of 20 sec are achieved by the use of a dual-bin tape storage transport design with start and stop-times of less than 1½ μsec. Digital densities of 1,000 phase modulation bits per lineal inch and higher are possible through the use of a raw tape slot guide which holds total skew to a maximum of 3 μsec across 1-inch tape at 150"/sec. Speeds to 300"/sec can be achieved.—*Shepherd Industries, Inc.*, 103 *Park Ave., Nutley* 10, *N. J.*

CIRCLE 327 ON READER-SERVICE CARD

C AND S ELECTRONIC WEIGHING SYSTEMS measure FORCE·THRUST·WEIGHT

...high accuracy
...high stability

C AND S Electronic Weighing Systems provide the high accuracy and stability demanded today ... for example, to measure the thrust of jet engines, or to weigh aircraft. Systems supplied by Revere include:

CALIBRATION AND TEST
The CS-17 Force Calibrator with direct digital readout is the heart of completely instrumented hydraulic test stands used to calibrate load cells. Dead weight machines with a wide range of capacities are available for lab work.
WEIGHT AND CENTER OF GRAVITY
C AND S Electronic Weighing Kits do more than 90% of all aircraft weighing today. And major missile projects – Jupiter, Atlas, Polaris – are depending more and more on these kits; guaranteed accuracies of 0.1%.
FORCE AND THRUST
Fully instrumented systems using C AND S Precision Load Cells in a wide range of capacities are custom-designed to test jet and rocket engines.

CALL ON REVERE ... WHEN YOUR PROJECT RATES THE BEST RATHER THAN "OFF-THE-SHELF" TREATMENT

when you want engineering abilities and specialized facilities in the fields of:

- Liquid Level Indication and Control
- Flow Indication and Control
- Flow Measurement
- High Temperature Wire and Cable
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- Thermocouples, Harnesses and Leads
- Electrical and Molded Harnesses
- Weight, Force and Thrust Measurement
- Determination of Center of Gravity
- Strain Gage Load Cells

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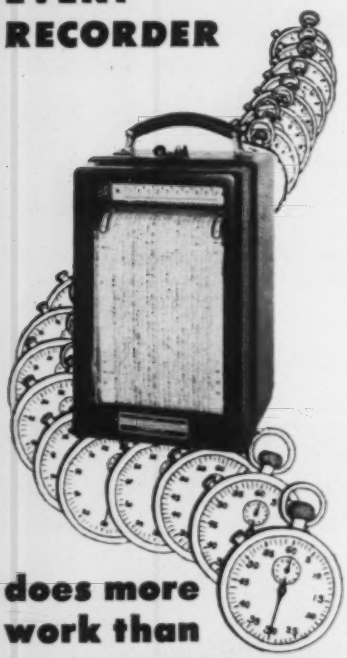
One of Neptune Meter Company's Electronic subsidiaries

CIRCLE 154 ON READER-SERVICE CARD

This One E-A

EVENT RECORDER



does more work than

20 STOP WATCHES

Each of the 20 pens, writing on a moving, time-calibrated chart can give you split-second, stop watch timing of individual events.

In addition, the time relationships of the events are also recorded. With an E-A Event Recorder, you can have a permanent, indisputable record of such things as:

- **Productive and idle time.**
- **Flow of materials.**
- **Position of gates and dampers.**
- **Time of failure in destruction tests.**
- **Sequence of switching as in —appliance control testing, —electrical substation monitoring, —missile firing.**

You save time and costs with these versatile recorders which "picture" both sequence and duration of events—in production and processing . . . in research . . . in plant safety.

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CIRCLE 155 ON READER-SERVICE CARD

ICS NEW LITERATURE

VALVES

GRAPHITE DIAPHRAGM VALVES. 5-page Bulletin 1610 covers three modifications of Impervite impervious-graphite diaphragm valves.—Falls Industries, Inc., Solon, Ohio.

CIRCLE 328 ON READER-SERVICE CARD

OIL FLOW CONTROL VALVE. 4-page Data Sheet GA704FC describes features of a Micro-Cam oil valve designed for precision control of oil flow of any type burner.—Hauck Mfg. Co., 124-136 Tenth St., Brooklyn 15, N. Y.

CIRCLE 329 ON READER-SERVICE CARD

CYLINDER VALVES. 16-page Catalog GA describes complete line of cylinder valves.—Bastian-Blessing Co., 4201 W. Peterson Ave., Chicago 46, Ill.

CIRCLE 330 ON READER-SERVICE CARD

TEMPERATURE

THERMOCOUPLE ASSEMBLIES. 16-page Catalog G100-4 outlines new MegopaK line of hard-pack, small-diameter, mineral-insulated thermocouples.—Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne and Windrim Ave., Phila. 44, Pa.

CIRCLE 331 ON READER-SERVICE CARD

THERMOCOUPLE PYROMETERS. 4-page Bulletin 8-60 describes three models pyrometer-millivoltmeters for measuring temperatures with thermocouples; installation, operation, and selection.—Lewis Engineering Co., Naugatuck, Conn.

CIRCLE 332 ON READER-SERVICE CARD

THERMOCOUPLES & ASSEMBLIES. 6-page Catalog TT-306 covers base- and noble-metal thermocouples, and thermocouple assemblies. Temperature ranges and performance specifications are provided for every tvpe.—Trinity Equipment Corp., Cortland, N. Y.

CIRCLE 333 ON READER-SERVICE CARD

OPTICAL PYROMETERS. 6-page Data Sheet ND42-35(1) describes line of optical pyrometers for temperature measurements up to 7600°F or 4200°C in plant or laboratory.—Leeds & Northrup Co., 4934 Stenton Ave., Phila. 44, Pa.

CIRCLE 334 ON READER-SERVICE CARD

TEMPERATURE REGULATORS. 8-page Catalog J180-1 contains information on the complete line of sliding-gate and plate temperature regulators.—OPW-Jordan, 6013 Wiehe Rd., Cincinnati 13, Ohio.

CIRCLE 335 ON READER-SERVICE CARD

METALLIC BELLOWS. 4-page Form BT436 illustrates and describes hydraulically and formed or welded bellows and assemblies with applications.—Bridgenort Thermostat Div., Robertshaw-Fulton Controls Co., Milford, Conn.

CIRCLE 336 ON READER-SERVICE CARD

TANTALUM THERMOWELLS. 4-page Bulletin F-1153 describes the standard line of tantalum thermowells and bulb sheaths used for protection of recording instruments in corrosive re-agents.—Fansteel Metallurgical Corp., Equipment Dept., North Chicago, Ill.

CIRCLE 337 ON READER-SERVICE CARD

INFRARED REFERENCE SOURCE. 8-page Bulletin 11-010 gives a comprehensive outline of the historical development and the scientific principles of black body infrared radiators and describes Opt. Therm radiation sources.—Barnes Engineering Co., 30 Commerce Rd., Stamford, Conn.

CIRCLE 338 ON READER-SERVICE CARD

FLOW, PUMPS, LEVEL

LIQUID LEVEL MAGNETIC GAGES. 6-page Catalog 388 covers in detail features, construction data, and operation of magnetic liquid level gages.—Jerguson Gage & Valve Co., 80 Adams St., Burlington, Mass.

CIRCLE 339 ON READER-SERVICE CARD

ROTARY FLOWMETER. 2-page Catalog Sheet CM-47 discusses the Vortex-Vel principle of fluid flow measurement and the operation of the line of Whirl-Flo flowmeters based on this principle.—Rotron Controls Corp., Woodstock, N. Y.

CIRCLE 340 ON READER-SERVICE CARD

MASS FUEL-FLOW MEASUREMENT. 4-page Bulletin GEZ-3072 describes mass flowmeter system for reciprocating and small gas turbine engines on helicopters, VTOL/STOL, and fixed-wing aircraft, as well as small industrial gas turbines.—General Electric Co., Schenectady 5, N. Y.

CIRCLE 341 ON READER-SERVICE CARD

CHEMICAL PUMPS. 4-page flyer lists suggested construction materials for metering pumps handling various chemicals.—Clark-Cooper Co., Inc., Palmyra, (Burlington Co), N. J.

CIRCLE 342 ON READER-SERVICE CARD

PROPORTIONING PUMPS. 8-page Bulletin 600 describes in detail four basic types of Vari-Flo pumps and their operations.—Blackmer Pump Co., Grand Rapids 9, Mich.

CIRCLE 343 ON READER-SERVICE CARD

SPEED, TIME

MOTOR-TACH GENERATORS. 2-page advance catalog technical data sheet gives complete specifications, data, and performance characteristics on Type 6252-03, size-11 motor-tach generator.—John Oster Mfg. Co., Avionic Div., 1 Main St., Racine, Wis.

CIRCLE 344 ON READER-SERVICE CARD

HAND SPEED INDICATOR. New 4-page brochure describes T110 Hand Speed Indicator, a combination counter and stop watch movement which stops and starts simultaneously. Can be used for speeds to 6,000 rpm on machines, motors, shaftings, etc. Has numerical readings, operates in either direction, and weighs only 8 oz.—Kernco Instruments, Inc., Box 1284, Church St. Sta., New York 8, N. Y.

CIRCLE 345 ON READER-SERVICE CARD

ELAPSED TIME INDICATORS. 2-page Bulletin 5001 illustrates and describes features of subminiature MIL-type indicator, Type WT-1.—Waltham Precision Instrument Co., Waltham 54, Mass.

CIRCLE 346 ON READER-SERVICE CARD

TRIPLE-RANGE ELECTRONIC STROBOSCOPE. New 6-page bulletin describes electro-optical stroboscope that measures speeds between 200 to 15,000 rpm, divided into three ranges.—Kernco Instruments, Inc., Box 1284, Church St. Sta., New York 8, N. Y.

CIRCLE 347 ON READER-SERVICE CARD

DATA HANDLING

MAGNETIC TAPE TRANSPORTS. 2-page Specification DS 3160 describes Series 3160 magnetic tape transports.—Minneapolis-Honeywell, Industrial Systems Div., 10721 Hanna St., Beltsville, Md.

CIRCLE 348 ON READER-SERVICE CARD

TAPE TRANSPORT SYSTEMS. 2-page bulletin describes the features of Type M3000 digital tape transport.—Midwestern Instruments, Box 7186, Tulsa 18, Okla.

CIRCLE 349 ON READER-SERVICE CARD

LANGUAGE TRANSLATORS. 4-page bulletin discusses types and techniques of code conversion.—Hermes Electronics Co., 75 Cambridge Parkway, Cambridge 42, Mass.

CIRCLE 350 ON READER-SERVICE CARD

COMPUTER APPLICATION. 6-page Application Report 14 explains in detail how the LGP-30 calculates incentive payroll, sales analysis and finished goods inventory at a steel forms manufacturing company.—Royal McBee Corp., Data Processing Div., Port Chester, N. Y.

CIRCLE 351 ON READER-SERVICE CARD

FORMAT CONTROL BUFFER. 4-page Data Sheet ZA-751 completely describes the principles of operation of the ZA-751 all-solid-state format control buffer together with technical specifications.—Electronic Engineering Co., 1601 East Chestnut Ave., Santa Ana, Calif.

CIRCLE 352 ON READER-SERVICE CARD

DIGITAL BUILDING BLOCKS. 4-page folder on 3000-Series digital test equipment describes building blocks which operate at speeds up to 500 kc and are priced to be economical in educational and control applications.—Digital Equipment Corp., Maynard, Mass.

CIRCLE 353 ON READER-SERVICE CARD

DIGITAL INFORMATION SYSTEM. 8-page Bulletin E72-2 lists complete specifications and describes operation of Metrotype Digital information System using all solid-state components.—Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio.

CIRCLE 354 ON READER-SERVICE CARD

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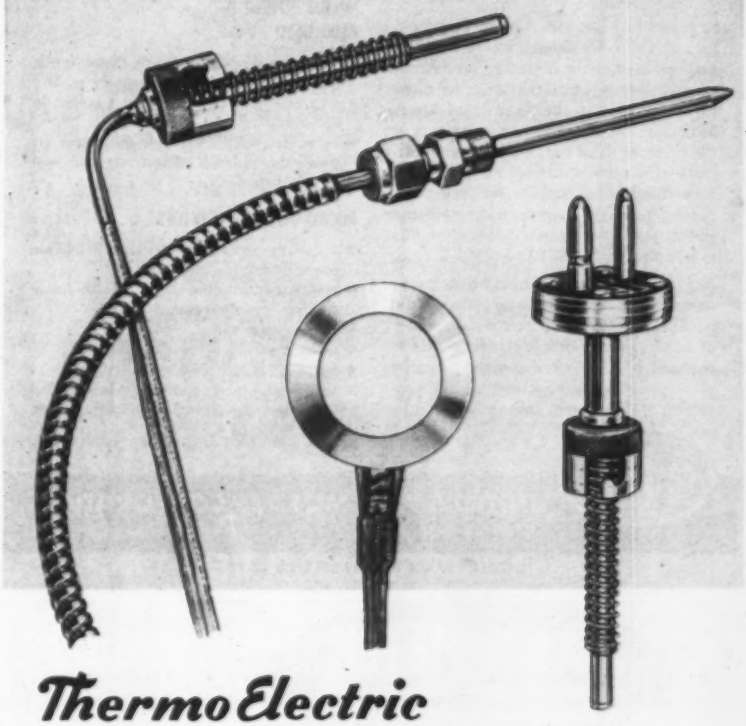
economy on the job!



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Protected thermocouples are extremely sensitive, give fast response to minute temperature changes. The measuring junction is welded or silver soldered to the tip of the thin-walled "Ceramo" metal sheath. Ideally used in corrosive liquids or gasses—and many pressure applications. For quick-coupling versatility, the spring-loaded bayonet-lock thermocouple is tops! You can use one "couple" at various depths with different adapters. With spring-loading, tip contact is always maintained. The bayonet type is highly sensitive, fast responding, for use in pump and engine cylinder heads, turbine housings, pipes, electric motors, generators, plastic extruders and molding machines.

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CIRCLE 156 ON READER-SERVICE CARD

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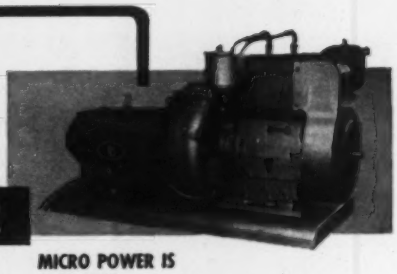
assures effectiveness of its protective boiler flame controls with . . .



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In plants like Douglas Aircraft Company, Inc., in Tulsa, Oklahoma, where a continual supply of steam is vital to production processes, every precaution must be taken to assure against the hazards of boiler flame-out. To safely regulate its burners in the event of flame-out, the company utilizes highly sensitive electric controls. Since these flame failure controls *are* electric and must depend on a constant, unwavering power supply for successful operation, this is achieved with MICRO POWER.

At Douglas Aircraft in Tulsa, Micro Power serves as the dependable rear guard to the boiler room. It provides a constant source of steady, independent electrical power as required by the safety controls, thereby eliminating voltage fluctuations and protecting against power failure.

MICRO POWER IS ALSO USED . . .

- on microwave systems for communications, for remote control, for telemetering.
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FOR MEASURING TANK CONTENTS ANY DISTANCE AWAY

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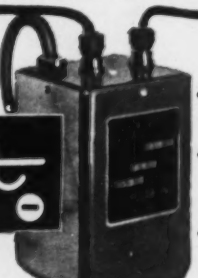

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CIRCLE 159 ON READER-SERVICE CARD

IGS NEW LITERATURE

DATA COLLECTOR. 8-page bulletin describes function and gives specs of Model 180 data gathering device.—Control Data Corp., 501 Park Ave., Minneapolis 15, Minn.

CIRCLE 355 ON READER-SERVICE CARD

AUTOMATIC TAPE DEGAUSSER. 2-page Bulletin 1631 describes the new DataTape 5-055A automatic tape degausser which erases signals from ¼- to two-inch magnetic tape.—Consolidated Electrodynamics Corp., a sub. of Bell & Howell Co., 360 Sierra Madre Villa, Pasadena, Calif.

CIRCLE 356 ON READER-SERVICE CARD

CONTROL TAPE, for machine-tool control and data processing applications is described in new Bulletin 1313. The tape is made of vulcanized fibre, and boasts toughness, durability, low stretch factor and high opacity.—National Vulcanized Fibre Co., 1060 Beech St., Wilmington 99, Del.

CIRCLE 357 ON READER-SERVICE CARD

EDUCATIONAL COMPUTER. 12-page Catalog S1 contains general description, specs, typical program, etc. of SPEC, a stored-program educational computer plus a digital differential analyzer, plus a digital logical design implementer.—Computer Control Co., Inc., 2251 Barry Ave., Los Angeles 64, Calif.

CIRCLE 358 ON READER-SERVICE CARD

ELECTRICAL, ELECTRONIC INSTRUMENTS

DIGITAL ELECTRIC INSTRUMENTS. 6-page short-form catalog features digital voltmeters, ratiometers, ohmmeters, voltage and resistance comparators, associated measuring equipment, and accessories.—Non-Linear Systems, Inc., Del Mar, Calif.

CIRCLE 359 ON READER-SERVICE CARD

PORTABLE PRECISION METERS. 4-page bulletin illustrates and describe light-spot type electrical measuring instruments made by Goerz in West Germany.—Physics Research Labs., Inc., Hempstead, N. Y.

CIRCLE 360 ON READER-SERVICE CARD

VARIABLE TRANSFORMERS. 4-page Data Sheet 1, explains and illustrates operating principles of the H-C Series Powersatt variable transformers.—Superior Electric Co., Dept. HC, Bristol, Conn.

CIRCLE 361 ON READER-SERVICE CARD

ELECTRONIC MEASURING SYSTEMS. 8-page Catalog G-101 contains illustrations and descriptions of thrust-weight-and-force measuring systems, weighing systems, strain gage instrumentation, and data handling systems.—Gilmore Industries, Inc., 13015 Woodland Ave., Cleveland 20, Ohio.

CIRCLE 362 ON READER-SERVICE CARD

TEST EQUIPMENT. 8-page short-form catalog and 4-page price list illustrate and describe tube testers, oscilloscopes, VTV's, stroboscopes, sound measuring equipment, etc.—Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland 8, Ohio.

CIRCLE 363 ON READER-SERVICE CARD

INSTRUMENT TRANSFORMERS. 4-page Bulletin 3-1.2 describes "Donut" current transformers for metering and allied applications.—Associated Research, Inc., of 3777 W. Belmont Ave., Chicago 18, Ill.

CIRCLE 364 ON READER-SERVICE CARD

ITV. 12-page pocket-size brochure gives pointers for installation of closed-circuit TV in business enterprises.— GPL Div., General Precision, Inc., 63 Bedford Rd., Pleasantville, N. Y.

CIRCLE 365 ON READER-SERVICE CARD

BRIDGE AMPLIFIER & METER. 2-page Bulletin 6 contains uses, features description, operation, and specs of Model BAM-1.—Ellis Associates, Box 77, Pelham, N. Y.

CIRCLE 366 ON READER-SERVICE CARD

MECHANICAL COMPONENTS

AIR CYLINDERS. 88-page catalog illustrates and describes complete lines of air cylinders, valves, clamps, and dial feed tables. Price lists are included.—Allenair Corp., 255 East 2nd St., Mineola, N. Y.

CIRCLE 367 ON READER-SERVICE CARD

INSTRUMENT BEARINGS. 4-page Bulletin 52-R-2 illustrates and describes non-freezing instrument bearings made as a replaceable sealed-pack unit.—Industrial Instrument Corp., Drawer 777, Austin, Tex.

CIRCLE 368 ON READER-SERVICE CARD

RUPTURE DISCS. 12-page Bulletin EI-4509-1 describes rupture discs, and illustrates and tabulates safety head assemblies.—Baker Platinum Div., Engelhard Industries, 113 Astor St., Newark 2, N. J.

CIRCLE 369 ON READER-SERVICE CARD

MISCELLANEOUS

INDICATING CONTROLLERS. 6-page Bulletin DMO58 describes the new Series 624 indicating pneumatic controllers. Models are listed for controlling pressure, vacuum, liquid level, flow, temperature, and humidity.—Bristol Co., Waterbury 20, Conn.

CIRCLE 370 ON READER-SERVICE CARD

TUBING FOR AERO INDUSTRIES. 12-page Bulletin 372 describes tubing for aircraft, missiles, and rockets.—Superior Tube Co., Norristown, Penna.

CIRCLE 371 ON READER-SERVICE CARD

DENSITY CONTROL. 2-page Bulletin SD-1 deals with the problems of sludge handling and pumping in treatment plants.—Ohmart Corp., 2236 Bogen St., Cincinnati 22, Ohio.

CIRCLE 372 ON READER-SERVICE CARD

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Model HT-12 Four-Range Tachometer

Centrifugal tachometer that measures revolutions per minute and surface speeds.

TOTAL RANGE: 90-12,000 RPM
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2nd — 300-1200 RPM
3rd — 900-3600 RPM
4th — 3000-12000 RPM
Feet per minute—one half the dial reading with use of 6" disc wheel.
Price — $80.00

Advantages: Accuracy—±0.5% • Stop button feature • Instantaneous readings • 3" easy to read dial • Light—approx. 14 oz.

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GRA LAB INTERVAL TIMER Automatic signalling and switching over unusually wide range of 3600 possible setting.

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For Precise and Rapid Measurements of
SHAFT SPEEDS CUTTING SPEEDS SURFACE SPEEDS

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CIRCLE 166 ON READER-SERVICE CARD

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PORTABLE AND STATIONARY
BULLETIN NO. 1048

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CIRCLE 167 ON READER-SERVICE CARD

ICS NEW LITERATURE

REPLACEMENT CHART PAPER. 14-page catalog lists replacement strip chart papers for all makes and models of recorders with cross references to recorder manufacturers' model numbers.—Judson Bigelow Sales Div., Techni-Rite Electronics, Inc., Box 3575-F, Providence 10, R. I.

CIRCLE 373 ON READER-SERVICE CARD

ADSORPTION MEASUREMENT. 2-page brochure describes the Model 212 Sorptometer, an instrument for rapid, accurate measurement of surface areas of solids and other adsorption phenomena.—Perkin-Elmer Corp., Instrument Div., Norwalk, Conn.

CIRCLE 374 ON READER-SERVICE CARD

ROTARY AIR COMPRESSOR. 4-page Bulletin E-269 illustrates, describes, illustrates, and specifies vane-type rotary air compressor for 100-lb service.—Davey Compressor Co., 600 Franklin Ave., Kent, Ohio.

CIRCLE 375 ON READER-SERVICE CARD

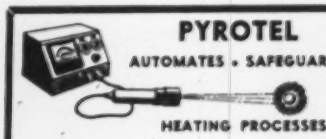
SWITCHES. 56-page pocket catalog, Booklet 60, of electric motor controls contains descriptions, ratings and prices for manual and magnetic starters, drum controllers, pressure, foot and limit switches.—Furnas Electric Co., 1164 McKee St., Batavia, Ill.

CIRCLE 376 ON READER-SERVICE CARD

ROTAMETERS. magnetic and electronic alarm, are described in new Bulletin 18A. Made to activate warning light or alarm device, start or stop pump, motor or control unit, both rotameters insure high accuracy for critical applications.—Schutte & Koerting Co., Cornwalls Heights, Bucks Co., Penna.

CIRCLE 377 ON READER-SERVICE CARD

PYROTEL
AUTOMATES • SAFEGUARDS



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INDUSTRY NEWS

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ASSOCIATED RESEARCH announces that *Richard W. Inman* has been named president.

NEELY ENTERPRISES, largest electronic manufacturers' representation firm in the country, is building a two-story. 10,000-sq-ft addition to its headquarters building in North Hollywood, Calif.

LABORATORY FOR ELECTRONICS has acquired 100,000 sq ft of plant and office space in a building adjacent to its headquarters.

MINNEAPOLIS-HONEYWELL announces formation of a Special Systems Division headquartered at Pottstown, Pa. for the development, installation, and servicing of complex integrated control systems for industrial and military application. The new corporate division will report directly to the president rather than being assigned to an existing product group.

COMMUNICATIONS AND CONTROL DIVISION OF FRANKLIN ELECTRONICS Incorporated will operate as a new and separate corporation—**COMMUNICATIONS CONTROL CORPORATION.** President is *Dr. Martin L. Klein.* With additional capital provided by the Electronics Capital Corporation, the company has initiated an immediate expansion program. New enlarged facilities will be occupied on September 1st at 14707 Keswick Ave., Van Nuys, Calif. Products include digital voltmeters, moisture sensing gages, and data acquisition systems.

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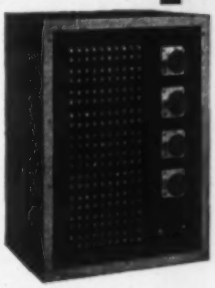

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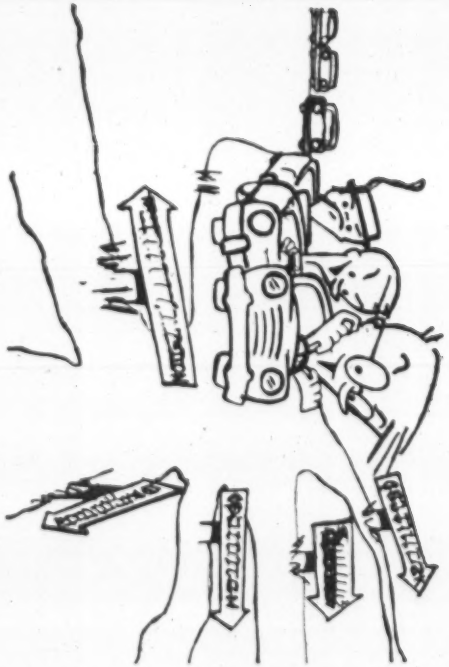

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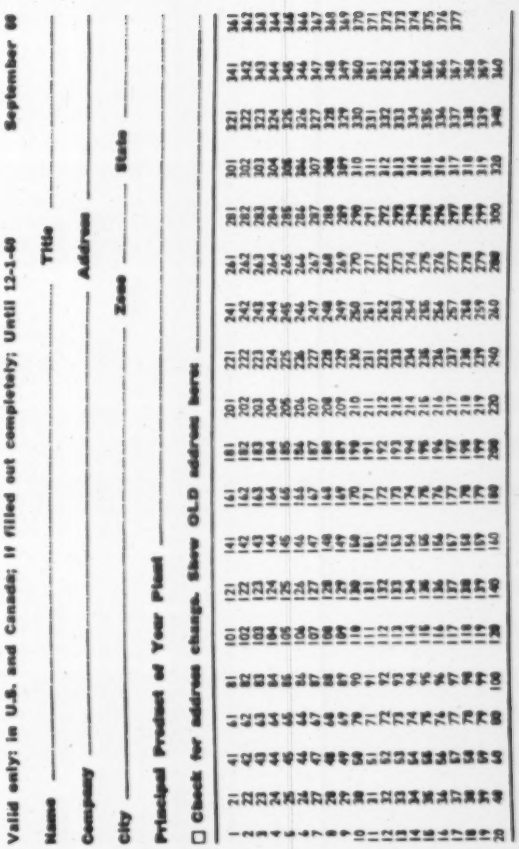

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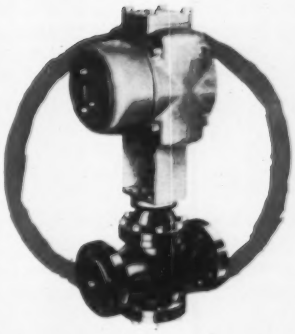

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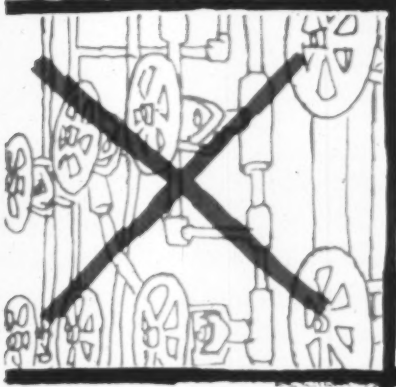

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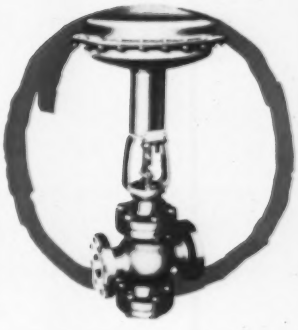

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MODEL 843
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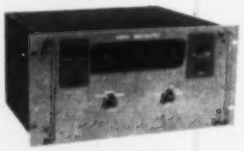

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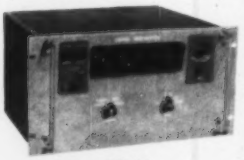

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